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Ice Baby

SECRETS OF A FROZEN MAMMOTH

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SHOULD WE CLONE EXTINCT ANIMALS? 52 • SEARCHING FOR SHANGRI-LA 56

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NATIONAL GEOGRAPHIC

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Special Supplement: Arctic Ocean/Arctic Ice

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The Three Parallel Rivers area in southwestern China is home to Shangri-La—and village markets where game and eggs are sold. Story on page 56.

FRITZ HOFFMANN

NATIONAL GEOGRAPHIC

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Flashback



BRIAN SKERRY

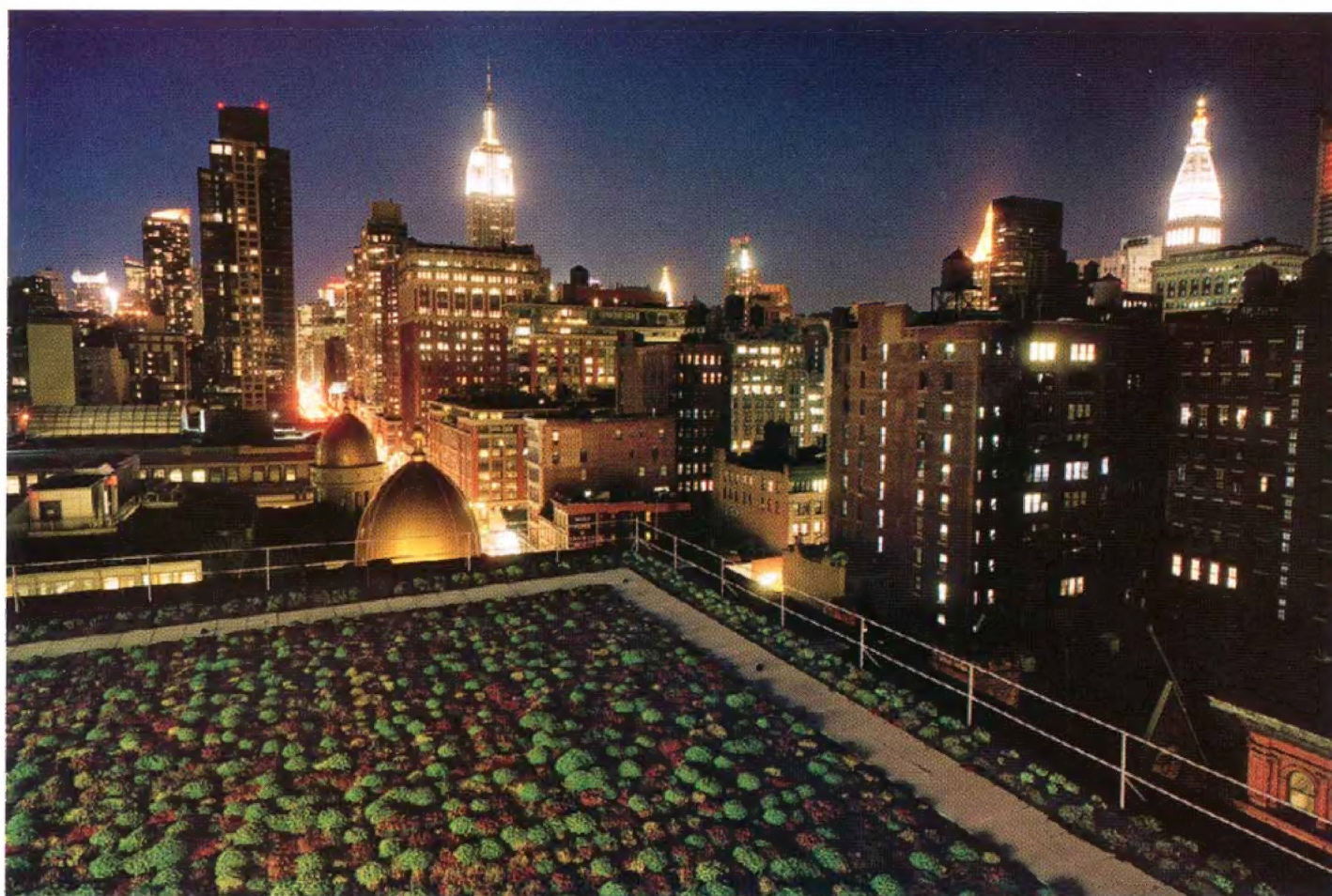
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🐢 **Turtle Stalking** Photographer Brian Skerry slept on a beach for two weeks as he pursued the elusive leatherback turtle. Listen to him tell the stories behind his pictures.

On the Cover

The baby mammoth left a museum freezer in St. Petersburg for this portrait. Photo by Francis Latreille

EDITOR'S NOTE



High atop a building on the Avenue of the Americas, a secret garden thrives outside the offices of a New York City architectural firm.



We talk a lot about the hardware of environmentally responsible buildings, like double-pane windows, energy-efficient heat pumps, and compact fluorescent bulbs. Those are unarguably important and necessary, but it's difficult to feel uplifted by the sight of a roll of R-38 fiberglass insulation.

That's what makes this month's story on green roofs so engaging. Here is where being responsible and attuned to the environment pairs up with spiritual satisfaction. I defy you to look at the image on pages 86-87 of the cottage-like garden atop a Manhattan apartment roof and not smile.

There's nothing new about the idea. The Greek historian Diodorus Siculus wrote about the Hanging Gardens of Babylon, a lavish profusion of greenery constructed by laying reeds set in tar on stone beams, then layers of brick, lead, and finally "enough topsoil was heaped to allow the biggest trees to take root."

What is new and current is the force of will displayed by cities like Stuttgart, Germany—the Germans are leaders in green-roof technologies and subsidize research—or Basel, Switzerland, where greenery is mandatory on new flat roofs.

It's the best kind of quid pro quo, writes Verlyn Klinkenborg. It turns the negative space of an arid roofscape into a positive—a collaboration with, instead of usurpation of, nature. In return, one harvests this: wildlife habitat, a moderating force for the high temperatures of asphalt rooftops, a buffer against destructive runoff, and most tellingly—smiles.



Inspiring people to care about the planet

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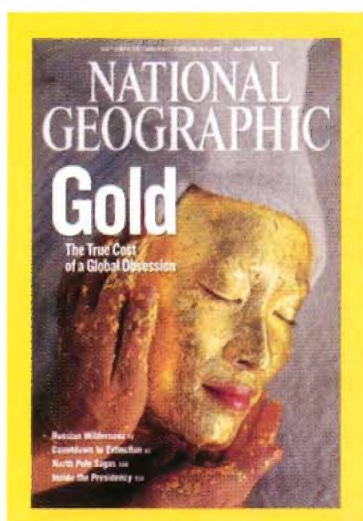
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LETTERS



January 2009

The Price of Gold

Gold simply teaches that humans are enslaved by their imagination. Practical need and necessity drive the imagination less than wholly subjective values—trust and faith in the metaphysical. In the interest of owning gold, humans will rain ruin on life, limb, and property, destroy cultures and the environment, and wreck peace only to hold a substance of limited utility. Less than 13 percent of gold is used for industrial and dental purposes, while the remaining 87 percent is for jewelry, retail investment, and exchange-traded funds.

STUART N. LUTTICH
Geneva, Nebraska

Searching for a way to convince the world not to value gold would be a modern equivalent of the medieval alchemist's search for a way to turn iron into gold. But I have long wondered why some brilliant scientist cannot find an alternative to mercury as a way of processing gold. Surely the by-product of mercury is one of the worst ways that the gold craze threatens the world.

NORM MUNDHENK
Mount Hagen, Papua New Guinea

Wouldn't it be more accurate to describe Newmont Mining Corporation's Batu Hijau mine as primarily a producer of copper with gold as a secondary product? It is the mining of copper that produces such a great mass of waste materials. Why, then, does gold get your blame? Gold is just an attractive mineral along for the ride.

PHILIP W. LAWSON
Casper, Wyoming

Poverty-driven artisanal mining remains a key concern for responsible gold-mining companies. Members of World Gold Council (WGC), who account for more than 60 percent of total corporate gold production, adhere to regional and international safety and environment guidelines. Some of these companies also have dedicated programs to directly help artisanal miners produce gold more safely or to find alternative sources of work. WGC also recognizes Communities and Small-Scale Mining, a global organization that works to reduce poverty by improving the environmental, social, and economic performance of artisanal and small-scale mining in developing countries. The vast majority of gold supply comes from legal and reputable sources, which your article failed to recognize.

ARAM SHISHMANIAN
CEO, World Gold Council
London, England

Last One

I take issue with your final sentence in "Last One." ["The better the chances of survival for the plants and animals and insects you see in these photographs—and for all their endangered kin—the better

our own chances will be."] Our survival is not explicitly linked to the survivability of other species now living on Earth. Species disappear when their habitat disappears and they are unable to adapt to a new one. This is not a moral problem. It is the very nature of evolution on Earth and has been happening for a billion years. More species have gone extinct by virtue of natural geologic forces than ever will by human folly. Our fate will likely be no different.

A. ELIZABETH JONES CRAFTFORD
Anchorage, Alaska

Your January editor's note explains that photographer Joel Sartore chose to stay close to his family while his wife, Kathy, successfully battled breast cancer. Other cancer survivors can thank the chemotherapy drug taxol, derived from the Pacific yew. Considered a "trash tree" and discarded as logging waste, its numbers declined until it was protected by the 1992 Pacific Yew Act. Those who can't accept preserving species could learn from the yew. Why should a rare bird, an endangered mouse, or some threatened plant be favored over human development? One answer: They, like the yew, might hold the cure for cancer.

ANGUS M. THUERMER, JR.
Jackson Hole, Wyoming

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Write National Geographic Magazine, PO Box 98199, Washington, DC 20090-8199. Include name, address, and daytime telephone. Letters may be edited for clarity and length.

Thank you for the timely reminder about the loss of biodiversity. In my home country of Australia, more than 20 percent of all mammals are now threatened with extinction, in a country with a population of 20 million people.

DANIEL MCKENZIE
Newcastle, Australia

I agree with the author that monitoring the survival of other parts of creation is one of the best ways to predict the direction we as humans will go. Something I do struggle with is how much money is spent on keeping plants and animals alive, while around the world so many people are dying needlessly for lack of basics. This is our only chance we have on Earth, so let's make the most of it for ourselves and all who share the space with us.

JONATHAN STEWARD
Trout Lake, Washington

Inside the Presidency

I fear the "Imperial Presidency" has become a reality. Our Presidents disappear behind the gates of the Forbidden City, isolated and advised by thousands of eunuchs, never to hear the voices of the people beyond the waters of the Potomac.

ROSS ANDERSON
Sutter Creek, California

When I flipped through "Inside the Presidency," my initial reaction to the article was that yet another publication was short shrifting President Bush. He is in several of the photos, though we never fully see his face. When I finally got enough time to read the entire article, I came to appreciate its perspective and understand

why the few faces shown were limited to those of the presidential staff. So, job well done, especially the final "Romp Ground" photo that captures so well President Bush's energy and eagerness to interact with those outside the door. Thanks for the insights (text and visual) into life as the leader of the United States and the free world.

MICHAEL VANVOOREN
Ballwin, Missouri

**Having savored
the heroic tales
of Peary, Scott,
Amundsen, Shack-
leton, Franklin, and
other polar explorers,
I do not know how
the exploits of
Norwegian hero
Fridtjof Nansen
have escaped me.**

As a Canadian citizen and a citizen of the world community, I take exception to author Elisabeth Bumiller's statement that the President of the United States is the leader of the free world. Where and when was this election ever held? I am sure that the leaders of the United Kingdom, Germany, Australia, Mexico, Canada, etc. would strongly disagree.

GARY CURTIS
Winchester, Ontario

Fridtjof Nansen: 1,000 Days in the Ice

Having savored the heroic tales of Peary, Scott, Amundsen,

Shackleton, Franklin, and other polar explorers, I do not know how the exploits of Norwegian hero Fridtjof Nansen have escaped me. It is easy to see how Børge Ousland grew up entranced by bedtime stories about Nansen. Nansen's ingenuity, engineering and mapping skills, fortitude, and physical endurance, in my opinion, are surpassed only by his superb photography.

ROD MASON
Pickering, Ontario

I had known nothing of this amazing man, but the article by Hampton Sides was so well written that I felt I knew Nansen well enough to get teary at the end.

BETTY MCLAIN
Seattle, Washington

Health: Hangover Helpers

I had just started to browse the January issue when I came across the page of cultural hangover cures. The best cure I have ever come across (aside from not drinking enough to become hung over in the first place) is to have 12 ounces of water for every drink (beer, wine, mixed drink, or shot) that you consume that night. While this may be more of a preventative measure, it works like a charm.

PAUL BOURDON
Muskegon, Michigan

Corrections, Clarifications

January 2009: The Price of Gold
Page 44: A typical wedding ring contains less than an ounce of gold.

Page 59: The conversions were incorrect. Fifty kilos of gold equal 134 troy pounds. Ten grams of gold equal .026 of a troy pound.

Park It Yellowstone, Yosemite, Shenandoah—we know you love the big National Parks. But do you know the smaller ones? The U.S. National Park Service manages parkland in and around urban areas all across the country. Find your own nearby park here: nps.gov/findapark. Grab your camera and visit. Then send us what you shoot. For guidelines, a submission form, and more information go to ngm.com/yourshot.

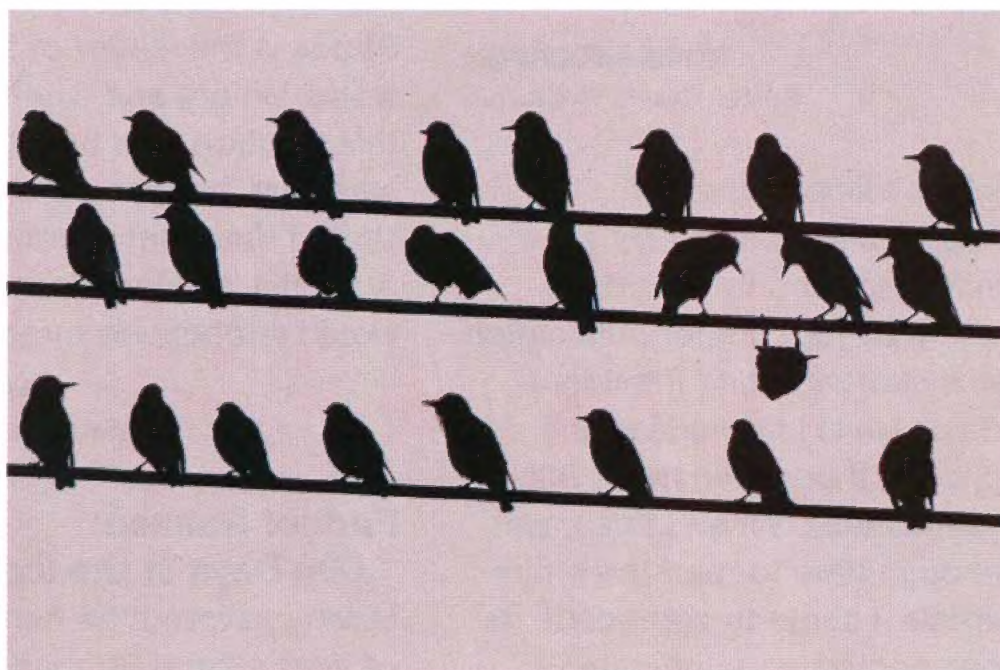


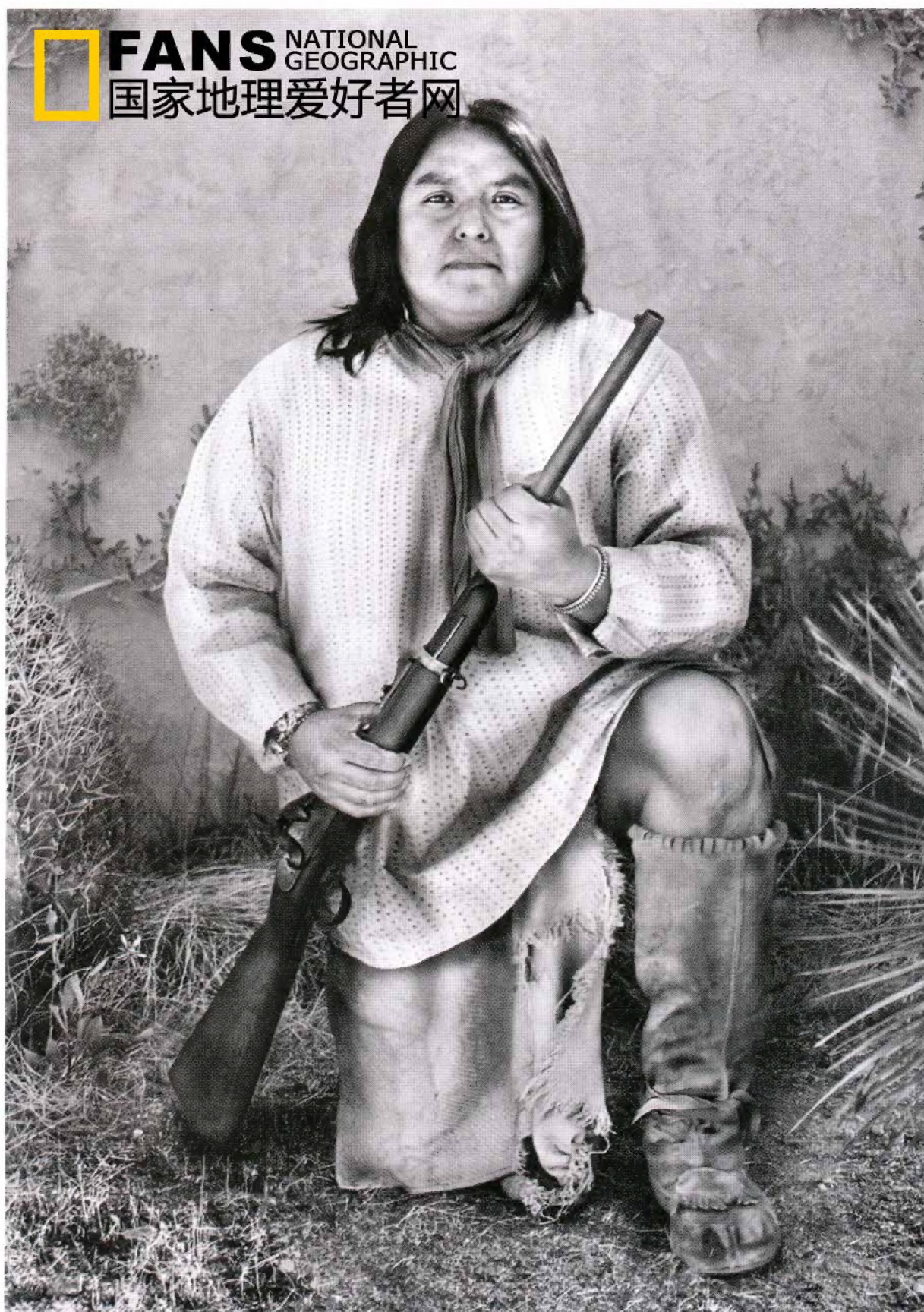
Gretchen Gann Austin, Texas

Kids on the Nicaraguan island of Ometepe set up chairs to watch the show as the Concepción volcano blows off some steam. The image by 29-year-old Gretchen Gann was voted an *ngm.com* audience favorite.

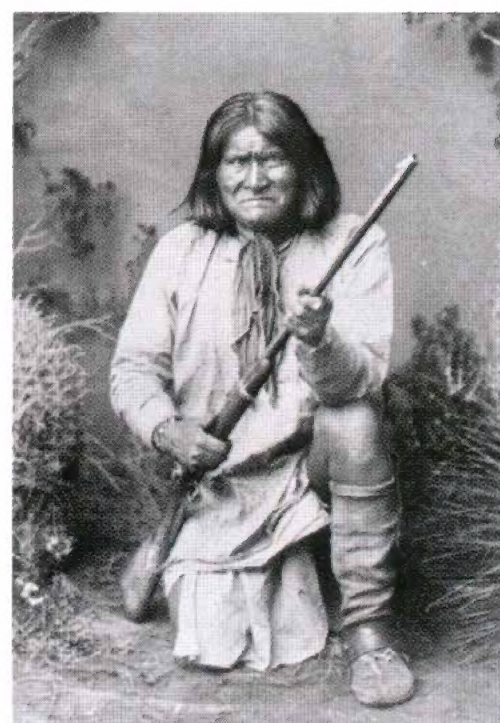
Hideta Nagai Columbus, Ohio

"I shot these birds just outside my building at work," says Hideta Nagai, 41. One landed badly and hung only briefly upside down—but it was long enough for Nagai to get his picture.





Robert Geronimo (above) is the great-grandson of the Chiricahua Apache hero.



More of Drew Gardner's work can be seen at drewgardner.co.uk.

Great Descendants History is wonderful but nebulous: hard to fathom, harder still to “see.” This project is my attempt to look it in the face, literally. By comparing modern people with their famous forebears—vital figures who shaped the world and continue to influence us—we can learn about how the past is passed down.

To create a pictorial family tree, I have to find descendants, verify lineage, acquire replicable portraits, get props and costumes, build backgrounds, mimic lighting. It's painstaking and inexact; you can see, for instance, that Geronimo (right, in 1886) and his scion hold slightly different rifles. But the work is worth it, even when ancestry isn't visually obvious. Most everyone wonders about their genealogy. I'm trying to satisfy that curiosity on a grand historical scale.

VISIONS OF EARTH

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South Georgia Island A snowy morning offers a peaceful study in contrasts as southern elephant seals and king penguins share a rookery. Antarctic spring brings some 400,000 of each species to this remote British territory.

PHOTO: YVA MOMATIUK AND JOHN EASTCOTT



England Lost in a wending laurel maze at Cornwall's Glendurgan—a series of verdant subtropical gardens planted privately in the 1820s and bequeathed to the National Trust in 1962—two visitors huddle in a hut.



PHOTO: BOB KRIST, CORBIS



China All is alabaster at a sculpture factory in Dangcheng, where marble and chalk dust suffuse the air and workers churn out relatively inexpensive copies of iconic Western works for foreign and domestic clients.



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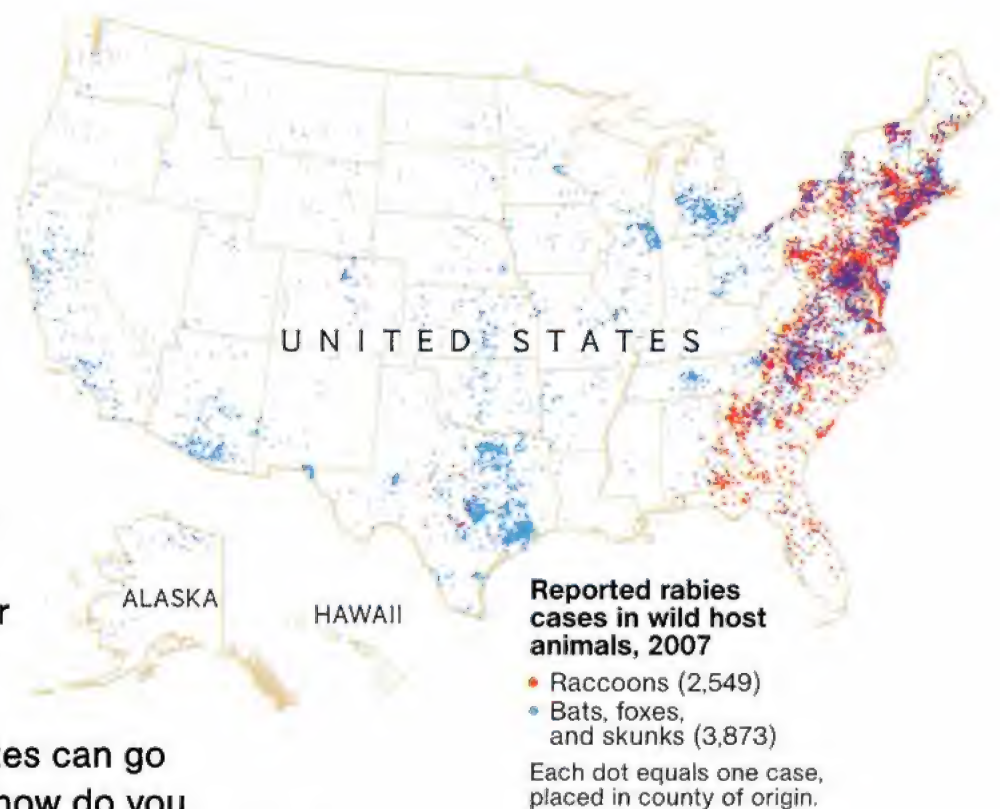
PHOTO: CHIARA GOIA, REPORTAGE BY GETTY IMAGES

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Rabies Bites It kills at least 50,000 people worldwide each year, mostly children. Dogs are the main culprits. But in the United States, where pet vaccination and stray-dog-control programs are strong, rabies has a different face: Raccoons and skunks are by far the top four-legged viral hosts.

Scientists are standing up to these rabid mammals. Since the early 1990s more than a hundred million doses of oral vaccine have been spread in problem areas to create buffer zones. Distribution continues. At the same time, another disease host is showing teeth. Widespread and mobile, bats are directly implicated in 20 of the 25 U.S. human rabies deaths since 1997. (Bat bites can go unnoticed, especially if the victim is asleep.) So how do you vaccinate on the wing? Ideas range from genetically modified insect prey to a parasite for drug delivery, says rabies expert Charles Rupprecht of the Centers for Disease Control and Prevention. Meanwhile, up to 40,000 U.S. bite victims yearly rely on a six-shot regimen in case of infection. Doctors who administer the drugs quickly haven't lost a patient yet. —Jennifer S. Holland



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This one is healthy, but raccoons are the top U.S. rabies hosts. Bats are number two. Dogs rank low, just above cattle.



In 2008 apparel imports to the United States totaled almost \$72 billion.

Sew Far Away

"Apparel always chases the low-cost needle." The garment industry tagline explains why more than 90 percent of clothing sold in the United States is made offshore, says Mike Todaro of the American Apparel Producers' Network. U.S. apparel manufacturing started in New England and New York in the 1800s, shifted to Pennsylvania, then headed south after the turn of the century to states where labor was cheap and unions were weak. From there, it jumped the border to even cheaper labor pools in Mexico and the Caribbean.

The rush to China began in the 1970s, remembers Bud Konheim, CEO of Nicole Miller, a women's wear designer. "We could do something for half price, so we did. Everyone went, like lemmings." Using tariffs and quotas to stem the hemorrhage has its limits. "They're easy to get around," Todaro says. Is the offshore shift irreversible? "We're beginning to hear that some production is coming back," he says. "But it's more feeling than fact." —Cathy Newman

GARMENT DISTRICTS

Nearly a third of U.S. apparel imports came from China in 2008. Asia and Latin America rounded out the top ten.

- 1 China (32% of imports)
- 2 Vietnam (7.3%)
- 3 Indonesia (5.63%)
- 4 Mexico (5.61%)
- 5 Bangladesh (4.8%)
- 6 India (4.3%)
- 7 Honduras (3.6%)
- 8 Cambodia (3.3%)
- 9 Thailand (2.4%)
- 10 Hong Kong (2.2%)



Elephants invade a backyard garden in Malaysia. Incursions are rising in Southeast Asia as farmers plant near forests.

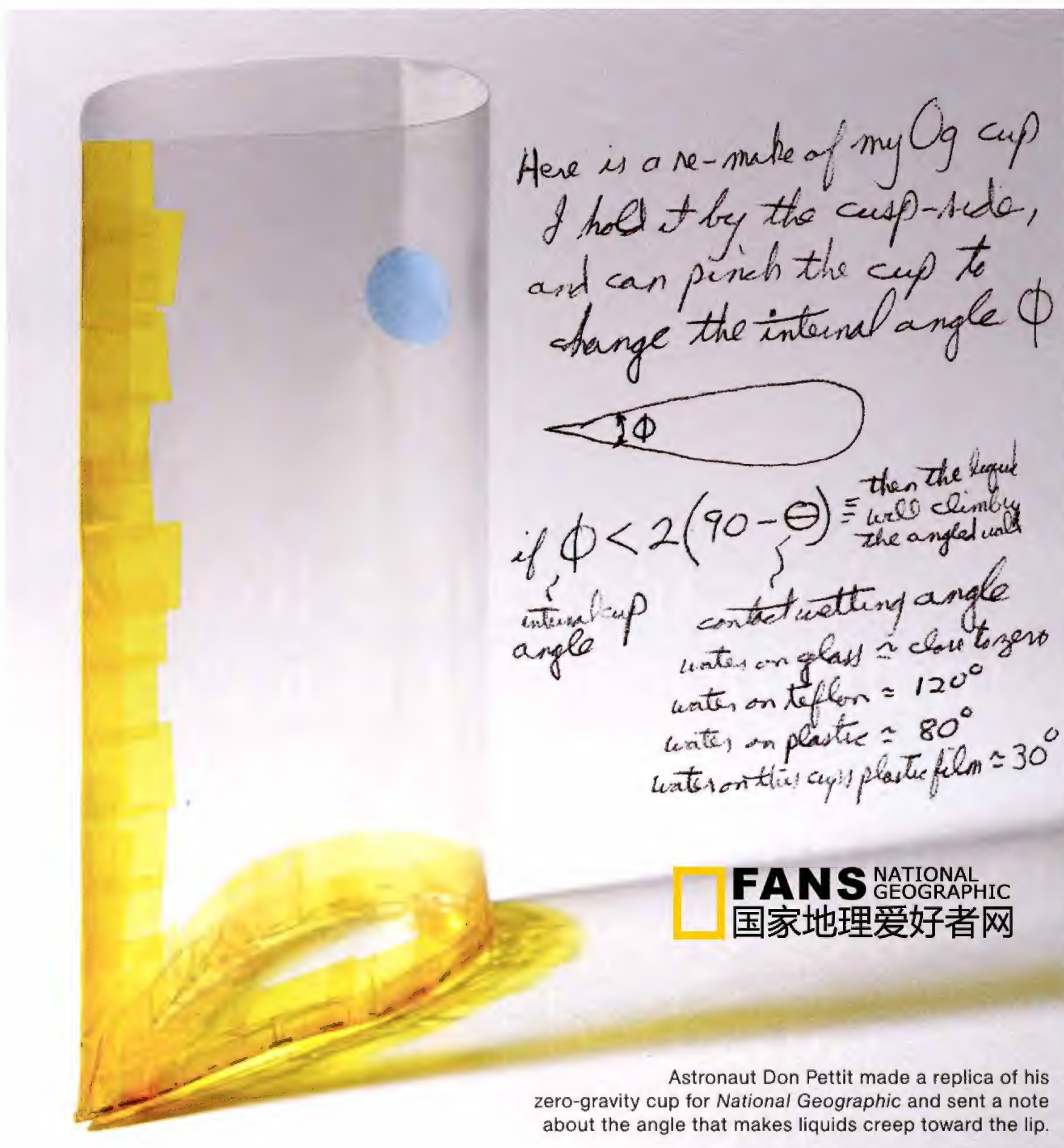
ELEPHANT REPELLENT

Here are some methods tried by farmers.

- Triple-strand electric fences run off car batteries (highly effective)
- Chili powder, tobacco, and engine oil painted on ropes (mixed results)
- Wires hung with plastic bags to mimic electric fences (not so much)
- Making noise or shooting firecrackers at elephants with slingshots (hit or miss)

Elephant Be Gone How do you keep a pachyderm out of your garden? That sounds like a wry riddle, but it's a real challenge in Southeast Asia, where hungry elephants emerge from forests to gobble crops. In the Salakpra region of western Thailand, 462 such raids cost farmers about \$30,000 in 2006 alone.

One novel answer to the problem: shimmering CDs. To keep elephants out of his irresistibly sweet sugarcane, Salakpra farmer Surachai Limpakanchanathawi took the advice of the Elephant Conservation Network and in 2007 hung CDs from fences, training spotlights on the discs. Swaying in the breeze, the illuminated CDs turned elephants around in their tracks—something single strands of electrified wire had often failed to do. Limpakanchanathawi soon abandoned the CDs for an even better method. With help from the army, his community dug a trench in an empty streambed between the forest and their fields. The ditch is 90 percent effective at halting elephants. No technique is guaranteed to work forever, though. "Elephants are intelligent," says researcher Belinda Stewart-Cox. "They suss things out." —Karen E. Lange




Astronaut Don Pettit made a replica of his zero-gravity cup for National Geographic and sent a note about the angle that makes liquids creep toward the lip.



Pettit imbibes on the space station.

Space Sip In zero gravity, astronauts crave earthly comforts. That's why they strap their heads to foam "pillows" at night. Alas, liquids pool or slosh and must be ingested from a pouch via straw. "You feel like an insect sucking juices out of another insect," says astronaut Don Pettit. So, on a mission last November, he made a cup from a plastic sheet sealed with tape. The sharp angle draws liquids to the lip—a force called capillary action, which pulls fuel into rocket engines. In a thousand years, he says, today's technology will be long gone, but space travelers will drink up from his cup. —Marc Silver



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A near-perfect frozen
mammoth resurfaces
after 40,000 years,
bearing clues
to a great
vanished
species. **Ice**

By Tom Mueller

*Photographs by
Francis Latreille*




Baby

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Discovered by reindeer herders and turned over to scientists, the ancient carcass began to thaw during an exam inside Shemanovsky Museum in Salekhard, Siberia. Members of the recovery team, Kirill Serotetto (at left) and Bernard Buigues, moved it outside to refreeze.

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Missing only toenails, part of her tail and right ear, and most of her hair, the new discovery is the most complete mammoth ever found.



The mammoth herd approaches the rushing river. A calf ambles close to her mother's huge legs, brushing their long, glossy hair now and then with her trunk. The sky is brilliant blue, and a dry wind hisses through the grasses, which billow like oceanic swells across a steppe 10,000 miles wide, spanning the northern arc of the Ice Age world. The long winter is over; birdsong and the scent of damp loam fill the air.

Perhaps the warmth of the sun makes the mother careless, and for a moment she loses track of her calf. The baby wanders toward the water. She stumbles on the slippery riverbank and slides into a slurry of clay, sand, and fresh snowmelt. She struggles to free herself, but every movement drags her deeper. The mud gets in her mouth, her trunk, her eyes; disoriented, she gasps for breath but gets a mouthful of muck instead. Coughing, gagging, caught

in a riptide of panic, she makes a dreadful high-pitched shriek that brings her mother running. Inhaling with all her force, the calf sucks the mud deep into her trachea, sealing her lungs. By the time her mother reaches the bank, the baby is partially submerged in the ice-cold mire and flailing feebly, rapidly sliding into shock. The mother screams and mills on the soft bank, drawing the rest of the herd. As they watch, the calf sinks beneath the surface.

Night falls. The herd moves on, but the mother lingers. Yellow moonlight throws her humpbacked shadow across the glistening mud. The moon sets, and stars glow in the chill heavens. Just before dawn, she takes a last look at the spot where the earth swallowed her baby, then turns and follows the herd north, toward summer pastures.

DISCOVERY

On a May morning in 2007, on the Yamal Peninsula in northwestern Siberia, a Nenets reindeer herder named Yuri Khudi stood with three of his sons on a sandbar on the Yuribey River, holding council over a diminutive corpse. Though they'd never seen such an animal before, they knew it well from stories their people sang on dark winter nights in their storytelling lodges. This was a baby *mamont*, the beast the Nenets say wanders the frozen blackness of the underworld, herded by infernal gods just as the Nenets herd their reindeer across the tundra. Khudi had seen many mammoth tusks, the honey-colored, corkscrew shafts as thick as tree limbs that his people found each summer. But he had never seen an entire animal, let alone one so eerily well preserved. Apart from its missing hair and toenails, it was perfectly intact.

Khudi was uneasy. He sensed this was an important discovery, one that others should know about. But he refused to touch the animal, because the Nenets believe that mammoths are dangerous omens. Some Nenets even say that people who find a mammoth are marked for early death. Khudi vowed to placate the infernal powers with the sacrifice of a baby reindeer and a libation of vodka. But first he traveled 150 miles south to the small town of Yar Sale to consult with an old friend named Kirill Serotetto, who was better acquainted with the ways of the outside world. Serotetto listened to his friend's story, then hustled him off to meet with the

director of the local museum, who persuaded the local authorities to fly Khudi and Serotetto back to the Yuribey River in a helicopter.

When they arrived on the sandbar, however, the mammoth had vanished.

LAND OF THE GIANTS

Mammoths are an extinct group of elephants of the genus *Mammuthus*, whose ancestors migrated out of Africa about 3.5 million years ago and spread across Eurasia, adapting to a range of woodland, savanna, and steppe environments. The best known of these proboscideans is the woolly mammoth, *Mammuthus primigenius*, a close cousin of living elephants and about the same size. It first appeared in the middle Pleistocene more than 400,000 years ago, probably in northeastern Siberia. The woolly mammoth was highly adapted to cold, with a dense undercoat, guard hairs up to three feet long, and small, fur-lined ears. Immense curving tusks, used primarily for fighting, may have also been handy for foraging beneath the snow. Because mammoths often died and were buried in sediment that has been frozen ever since, many of their remains have survived into modern times, particularly in the vast deep freeze of Siberian permafrost.

In fact, the Nenets' underworld tales are right: The Siberian subsoil teems with woolly mammoths. At ice-out each summer, hundreds of their tusks, other teeth, and bones appear on the banks of rivers and lakes and along the seacoast, freed by erosion from the frozen ground where they have lain for tens of thousands of years. Since the botanist Mikhail Ivanovich Adams recovered the first woolly mammoth carcass in Siberia in 1806, about a dozen other soft-tissue specimens had been found, including several calves ranging in age from newborn to about a year. Yet no carcass of any age was as complete as the creature Yuri Khudi had found—and now lost—on the Yuribey River.

In the time of the mammoths, the landscape over most of their range looked very different than the barren heaths and boggy tundra surrounding the river today. The air was

Tom Mueller wrote on Herod in the December 2008 issue of National Geographic. Francis Latreille has photographed for Life, Time, Paris-Match, and Geo. This is his first story for National Geographic.



Reindeer herder Yuri Khudi (at left) and sons found the carcass in Siberia's Yamal Peninsula in May 2007 and alerted local authorities. Mammoth remains commonly turn up in the region but often are sold to fossil dealers before scientists can examine them. In gratitude, officials named the calf Lyuba, after Khudi's wife.

drier, cloud cover was limited, and strong winds swept the electric blue skies. In place of tundra grew a vast, arid grassland that paleobiologist R. Dale Guthrie has called the mammoth steppe, stretching from Ireland to Kamchatka and across the Bering land bridge to Alaska, the Yukon, and much of North America. The grasses, broad-leaved herbs, and low shrubs of the steppe provided nutritious food, and in addition to mammoths, nourished a profusion of other outsize, exuberantly hairy mammalian megafauna—woolly rhinoceroses, enormous long-horned bison, and bear-size beavers, as well as the fearsome carnivores that hunted them: saber-toothed cats, cave hyenas, and giant short-faced bears.

Then, between 14,000 and 10,000 years ago, the mammoths disappeared from most of their range, along with most of the other large mammal

species in the Northern Hemisphere—as many as 70 percent in some regions. These extinctions were so sweeping that scientists have evoked a number of cataclysmic events to explain them—a meteorite strike, killer fires and droughts, and a virulent, cross-species hyperdisease. Since the extinctions coincided with the end of the most recent ice age, however, many researchers believe that the primary cause of the great die-off was the sharp rise in temperature, which dramatically altered the vegetation. A recent computer simulation of landscape changes during the late Pleistocene suggests that 90 percent of the mammoth's former habitat disappeared. "We have strong evidence that climate change played a significant part in their extinction," says Adrian Lister, a paleontologist and mammoth expert at the Natural History Museum in London. "In Eurasia,



Researchers transported the mammoth in a refrigerated container from Siberia to Jikei University's medical school in Tokyo to be CT scanned. Hospital officials insisted that handlers wear special suits and a plastic passage be erected to ensure that ancient bacteria from Lyuba would not contaminate their facility.

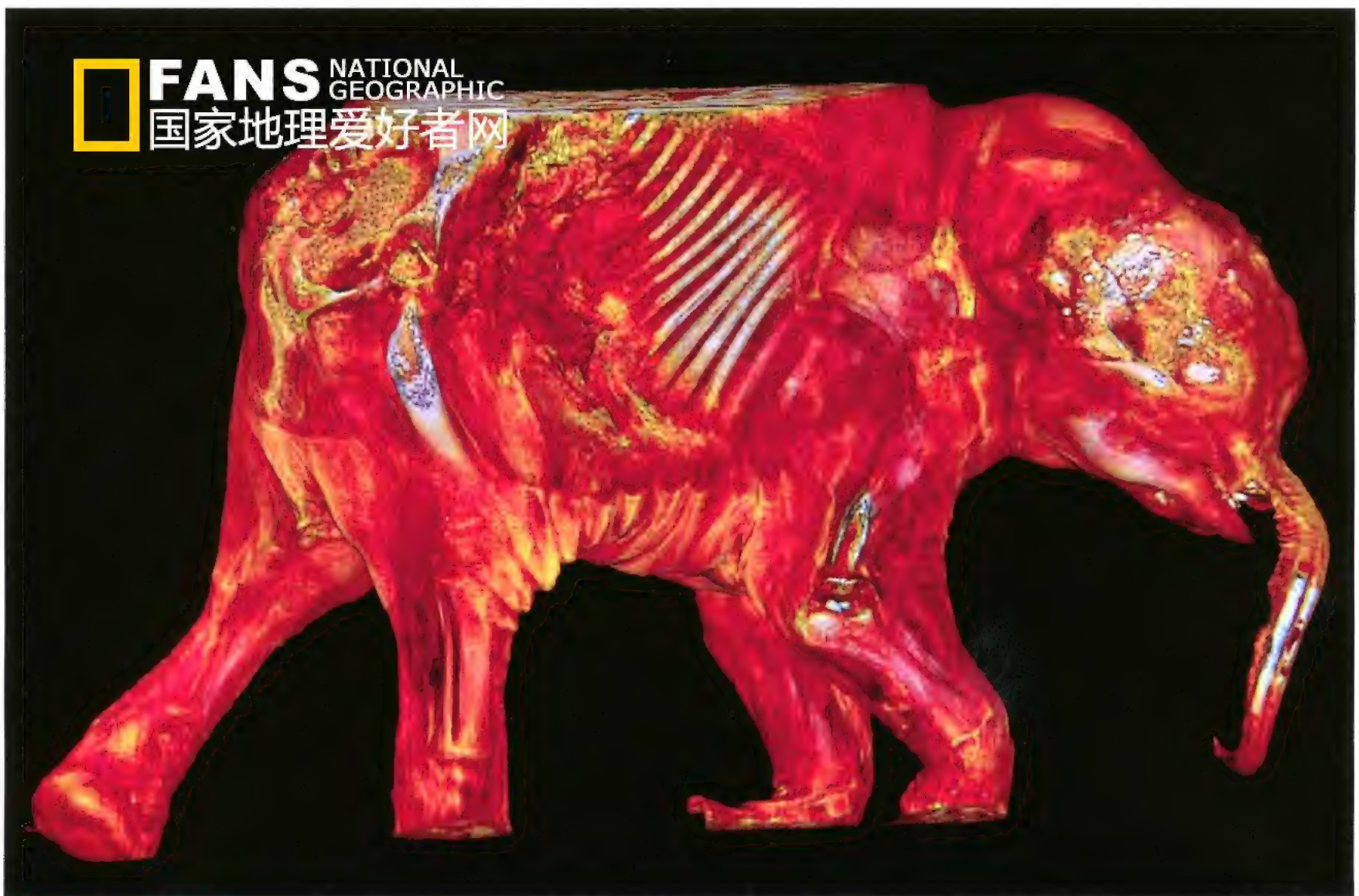
the timing of the two events matches closely.”

The extinctions also coincided, however, with the arrival of another ecology-altering force. Modern humans arose in Africa about 195,000 years ago and spread into northern Eurasia some 40,000 years ago. As time went on, their expanding populations brought increasing pressure to bear on prey species. In addition to exploiting mammoths for food—a big male killed in the autumn would see a band of hungry hunters through many lean winter days—they used their bones and ivory to make weapons, tools, figurines, and even dwellings. Some scientists believe that these human hunters, using throwing spears fitted with deadly stone points, were as much to blame as climate change for the great die-off. Some say they caused it. The debate over the megafaunal extinction is one of the liveliest in

paleontology today, and not one likely to be resolved by a single specimen, no matter how complete. But Khudi was right that the now missing baby—its flesh, internal organs, stomach contents, bones, milk tusks and other teeth, all intact—would be of enormous interest to the outside world.

He also suspected that a person willing to handle such a thing would probably turn a nice profit—ivory traders regularly visited the region to buy mammoth tusks, and who knows what they'd pay for an intact mammoth? Khudi's suspicions soon fell on one of his own cousins, whom some local Nenets had seen on the sandbar and later, riding away on his reindeer sled toward the town of Novyy Port.

Khudi and Serotetto set off in pursuit on a snowmobile. When they arrived, they found the little mammoth propped up against the wall of a



The CT scan provided detailed new insights into a mammoth's anatomy as well as important clues to Lyuba's death. Sediment found blocking the trunk's nasal passages (shown in white) and in the mouth, esophagus, and windpipe suggests that she asphyxiated by inhaling mud after becoming trapped in a mire.

store. People were taking snapshots of it on their cell phones. The shop owner had bought the body from Khudi's cousin for two snowmobiles and a year's worth of food. Though it was no longer quite perfect—stray dogs had gnawed off part of its tail and right ear—with the help of some local police, Khudi and Serotetto managed to reclaim the infant. The body was packed up and shipped by helicopter to the safety of the Shemanovsky Museum in Salekhard, the regional capital.

"Luckily there was a happy ending," says Alexei Tikhonov, director of the St. Petersburg Zoological Museum and one of the first scientists to view the baby, a female. "Yuri Khudi rescued the best preserved mammoth to come down to us from the Ice Age."


Grateful officials named her Lyuba, after Khudi's wife.

CLUES IN A TOOTH

Tikhonov knew that no one would be more excited by the find than Dan Fisher, an American colleague at the University of Michigan. Fisher is a soft-spoken, 59-year-old paleontologist with a bristly white beard and clear green eyes who has devoted much of the past 30 years to understanding the lives of Pleistocene mammoths and mastodons, combining fossil studies with some very hands-on experimental research. Curious to know how Paleolithic hunters managed to store mammoth meat without spoilage, Fisher butchered a draft horse using stone tools he'd knapped himself, then cached the meat in a stock pond. Naturally preserved by microbes called lactobacilli in the water, the flesh emitted a faintly sour, pickled odor that put off scavengers even when it floated to the surface. To test its palatability, Fisher cut and ate steaks

LYUBA'S DEATH

Scientists are still debating whether the calf suffocated in mud or drowned in water, but they agree she died quickly. Her body was immediately entombed in a mixture of silt and clay, setting in motion a process that preserved her for some 40,000 years.

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Height:
three feet
Weight:
220 pounds



FERNANDO G. BAPTISTA, NG STAFF;
MAMMOTH ART BY KAZUHIKO SANO
SOURCE: DANIEL C. FISHER,
UNIVERSITY OF MICHIGAN

SEALED IN TIME

How paleontologist Dan Fisher accounts for Lyuba's superb state of preservation:

- 1 Upon death she is submerged in wet clay and silt, which seal out oxygen and thwart aerobic microbes that would otherwise break down her soft tissue.



- 2 Other microbes that produce lactic acid colonize her tissues. The acid acts as a preservative, pickling her carcass.

- 3 As the ground turns to permafrost, her body dehydrates and shrinks to half its weight.



- 4 In 2006 a river undercuts a block of permafrost containing Lyuba. The block melts, exposing her body. Floodwaters wash it downstream to a sandbar. The smell of lactic acid wards off scavengers.



from the meat every two weeks from February until high summer, demonstrating that mammoth hunters might have stored their kills in the same way.

Tikhonov invited Fisher to Salekhard in July 2007, along with Bernard Buigues, a French mammoth hunter who had helped arrange scientific study of several previous mammoth discoveries. Both Fisher and Buigues had examined several other specimens, including infants. But they were in relatively poor condition, and little hands-on work was possible. Lyuba was another story entirely.

"When I saw her," Fisher says, "my first thought was, Oh my goodness, she's perfect—even her eyelashes are there! It looked like she'd just drifted off to sleep. Suddenly, what I'd been struggling to visualize for so long was lying right there for me to touch." Other than the missing hair and toenails, and the damage she'd sustained after her discovery, the only flaw in her pristine appearance was a curious dent in her face, just above the trunk. But her general appearance and the healthy hump of fat on the back of her neck suggested the baby had been in excellent condition at the time of her death. A deeper examination into her teeth, internal organs, stomach contents, and other features promised to reveal a wealth of new information on normal mammoth biology and lifeways.

Fisher was particularly excited about one specific part of Lyuba's anatomy: her milk tusks. Tusks are modified incisors that grow continuously in layers throughout an animal's life. Over 30 years of studying mammoth tusks, Fisher had figured out that these deposits were laid down in yearly, weekly, and even daily increments, and that, like the rings of a tree, they contained a detailed record of the animal's life history. Thick layers represented rich summer grazing, while thin ones indicated sparse winter fare. From a sudden narrowing of the strata around the 12th year, Fisher could discern when a young male became sexually mature and was driven away by its mother from the matriarchal herd; some years later came signs of the ferocious musth battles that adult males waged to

determine who would win the opportunity to mate. Finally, in the layers at the root of the tusk that are the last to form, Fisher found clues to how an animal died—a slow dwindling caused by injury, illness, or environmental stress, or the sharp break of sudden death. He also found that the levels of certain chemical elements and isotopes in the tusks provided data on the animal's diet, climatic situation, even major changes in location such as migration.

Through his career Fisher has taken hundreds of tusk samples, and he believes they suggest an answer to the vexing question of the great extinction in the late Pleistocene. At least in the Great Lakes region of North America, where the bulk of his samples were unearthed, mammoth and mastodon tusks show that these animals continued to thrive, despite late Pleistocene climate change. On the other hand, to Fisher, the tusks often revealed telltale evidence of human hunting. His samples from late in the mammoth's reign frequently came from animals that had died in the autumn, when they should have been at their physical peak after summer grazing and less likely to die of natural causes—but also when human hunters would have been most eager to stockpile food for the coming winter. These tusks often came from males, who, like living elephants, probably lived alone and would have made easier targets for hunters than females traveling in matriarchal herds. Many remains were found in peat bogs and bodies of water, where according to Fisher early hunters may have submerged them to preserve the meat. The North American specimens also appeared to show a decline through time in the average age of maturation, which Fisher believes might also be caused by hunting pressure. He had done limited work in Siberia, but his measurements of tusks from Wrangel Island, off the coast of northeastern Siberia, where the last mammoths died out 3,900 years ago, suggest similar conclusions.

One problem with interpreting mammoth tusks, however, was that they almost never came with mammoths attached, making it hard for Fisher to test his inferences about health and

age. Lyuba's superb state of preservation promised to change that. By giving direct evidence of her diet and state of health, her stomach and intestinal contents and the amount of fat on her body could provide an independent corroboration of the brief dietary "journal" recorded in her still unerupted milk tusks. "In this case we don't need a time machine to see how accurate our work is," Fisher says. Moreover, since the





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By late spring the ice-clotted rivers that lace Siberia's Yamal Peninsula have melted. Their rising currents cut chunks of permafrost from the shoreline. To see the region now is to view a snapshot of Lyuba's world, says paleontologist Dan Fisher. Most plant life is different, but the landscape resembles that of 40,000 years ago.

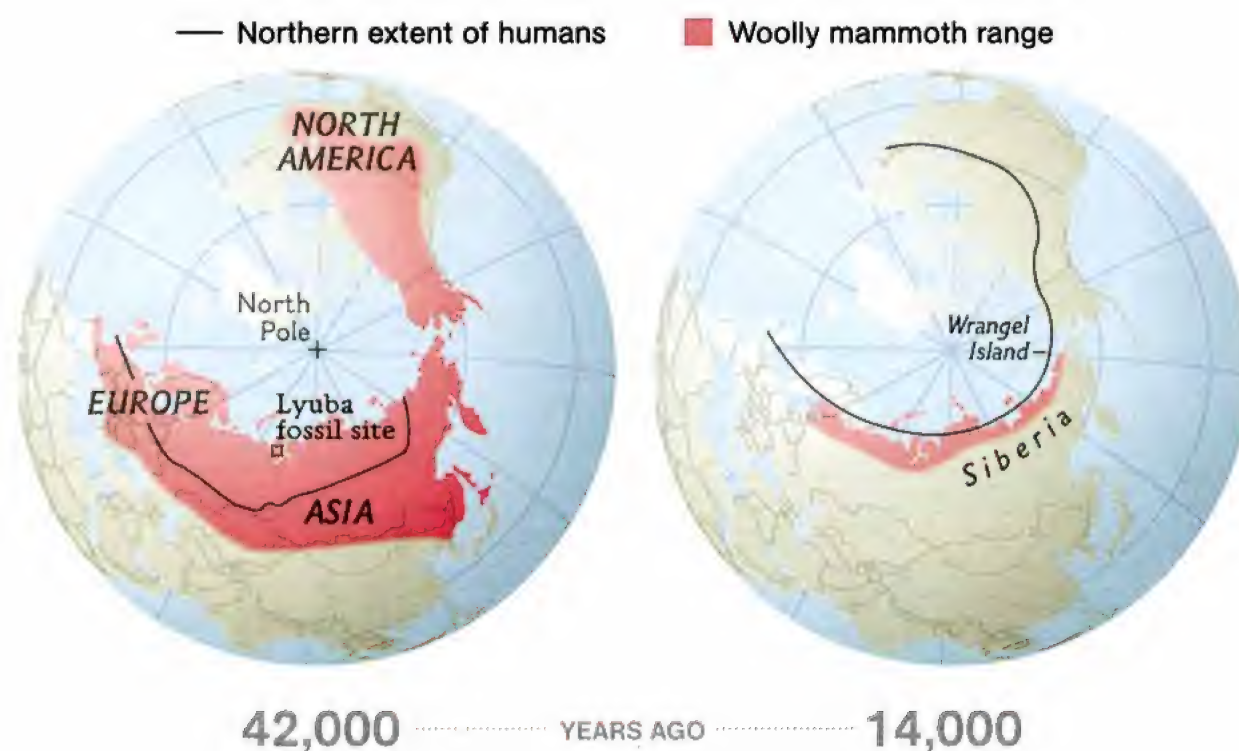
milk tusks grow from early in gestation to around the time of birth, Lyuba could shed new light on a critical period in a mammoth's life: the time in the womb (estimated to be 22 months, based on an elephant's gestation length), followed by birth. A traumatic event for any mammal, the moment of birth is recorded in tooth microstructure by a distinct neonatal line. By comparing her milk tusk development

with that of elephants, the scientists initially estimated her age at death to be four months. Counting the increments of ivory laid down after the neonatal line would provide a much more accurate age.

Fisher was also intrigued by the forensic mystery of how and why such an apparently healthy young life had been cut short—and whether it had anything to do with the odd deep dent

DAYS OF THE MAMMOTH

Well suited to cold, woolly mammoths flourished during the last ice age across the Northern Hemisphere. But a warming climate reduced their numbers to ever smaller, isolated populations. In some areas, human hunters may have hastened their extinction.



in her face. “That feature immediately leaped out, though at the time I had no idea what to make of it,” Fisher says.

To begin the analysis, tissue samples from Lyuba were sent to the Netherlands, where carbon-14 dating revealed she had died some 40,000 years ago. For scientists to probe deeper into her life, however, she would have to travel herself. In December 2007 Buigues arranged for the specimen to be transported to Japan by refrigerated container to undergo a CT scan by Naoki Suzuki of the Jikei University School of Medicine. The test confirmed her skeleton, teeth, and soft tissues were undamaged, and her internal organs seemed largely intact. The end of her trunk and her throat, mouth, and windpipe were filled with dense sediment, which suggested to Fisher that she had died by asphyxiation in mud. The scan also revealed

some odd x-ray-opaque blobs in her soft tissues and a distortion of certain bones. These anomalies underscored another conundrum: After 40 millennia in the ground—and who knows how long exposed on the surface—why was she so well preserved?

Lyuba’s remarkable condition appeared all the more mystifying in May 2008, when Fisher and Buigues visited the Yuribey River. Just upriver from the sandbar where she’d been found stood a high, sheer bluff, which was being steadily undercut by the river. Blocks of permafrost, some as big as houses, hung out over the rim of the bluff. Perhaps Lyuba had been frozen in such a block that had collapsed into the water during the previous thaw, floated downstream, and come to rest on the sandbar when the thaw-swollen river had briefly risen to that level. There was only one problem: Yuri Khudi’s sons had

found her there in May 2007, *before* the spring ice-out. Unless she had risen from the underworld and walked up onto the bar on her own, the only explanation was that she had broken out of the permafrost and come to rest there nearly a year before she was discovered, during the ice-out of June 2006. To Fisher, standing on the spot two years later, it just didn't make sense.

"She'd have been lying on this riverside all that time," he said to Buigues, "including an entire summer exposed to the sun. So why hasn't she decomposed or been scavenged?"

Fisher and Buigues had done what they could to understand the circumstances of the calf's death and mysterious preservation. Further answers would have to come from Lyuba herself.

AUTOPSY

On June 4, 2008, in a genetics laboratory in St. Petersburg, Russia, Fisher, Buigues, Suzuki, Alexei Tikhonov, and other colleagues, dressed in white Tyvek suits and surgical masks, began a marathon, three-day series of tests and surgical procedures on Lyuba. As she lay on a Plexiglas light table in the middle of the room, Suzuki inserted an endoscope into her abdominal cavity, to explore an open space he'd seen during the CT scan. Other scientists used an electric drill to take a core sample of the hump of fat on the back of her neck, searched for mites in her ears and hair, cut into her abdomen, and removed sections of her intestine to study what she had been eating. Finally, on the third day, Fisher cut into Lyuba's face and extracted a milk tusk, as well as four premolars.

Initially the researchers kept her frozen by surrounding her with plastic tubs of dry ice. Later, to facilitate the more invasive procedures, they allowed her to slowly thaw out, carefully monitoring her for signs of putrefaction. As her flesh warmed, Fisher noticed an odd, slightly sour smell, which he found familiar but couldn't quite place. "Like everybody else, I was suffering from sensory overload," he remembers. "We



In life Lyuba was covered with hair, but only traces of her undercoat remained (top). Layers of coarse hairs would have protected this woolly insulation, forming a dense coat that could combat minus 20°F temperatures. As she aged she would have developed cracks in her soles (above) to provide traction in snow, while fleshy pads behind her toes would have cushioned her steps—a vital trait had she reached an adult weight of six tons.

■ **Society Grant** This project was funded in part by your National Geographic Society membership.

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During an autopsy Dan Fisher extracts fecal matter from Lyuba's intestine. The feces probably came from Lyuba's mother, fed to the calf to aid growth of bacteria needed to digest vegetation. The mother's feces will help identify plants she ate and may yield her DNA.



Scientists cut a patch of skin and fat from Lyuba's abdomen. "This tells us as much about the mother as the baby," says Dan Fisher, noting that the healthy layer of white fat indicates the nursing calf was well fed. "If the mother had been ill or struggling to find food, we would expect this layer to be much thinner."

had to cram so much work into so little time. "I just made a mental note and moved on." He also noticed that the mammoth's teeth were not held in their sockets by the usual connective tissue, and her muscles had separated from the bone in places where, in a normal specimen, they would have been firmly bonded. "That totally blew me away," Fisher says. "I kept asking myself, What's going on here? What does this mean? But there wasn't much time for reflection."

The x-ray-opaque areas visible on the CT scan turned out to be brilliant blue crystals of vivianite, probably formed from phosphate leached out of her bones. Fisher noted a dense mix of clay and sand in her mouth and throat, which would support the hypothesis from the CT scan that she'd suffocated, probably in riverbank mud. In fact, the sediment in Lyuba's trunk was packed so tightly that Fisher saw it as

a possible explanation for the dent in her face. If she were frantically fighting for breath and inhaled convulsively, perhaps a partial vacuum was created in the base of her trunk, flattening its soft tissues against her forehead.

To Fisher, the circumstances of Lyuba's death were clear. (Suzuki would later propose a different interpretation, seeing more evidence for drowning than asphyxiation.) At the end of the autopsy, while Fisher and his colleagues were suturing up her little body, he also had a revelation about her peculiar smell. His mind at last relaxing after the intense effort of the past three days, he suddenly remembered his experiment with the draft horse and the smell that its bloated chunks of flesh, naturally pickled by lactobacilli, emitted as they bobbed on the surface of the pond. Lyuba had the same smell. Finally, her superb state of preservation

made sense. She had literally been pickled after she died, which protected her from rot once her body was exposed again, thousands of years later. The lactic acid produced by the microbes also could have caused the odd bone distortion and muscle separation that Fisher had noticed during the autopsy, and perhaps even encouraged the formation of vivianite crystals by freeing phosphate from her bones.

So Lyuba was probably killed by a misstep in or near a muddy river, and preserved for science by a combination of biochemical serendipity and the singular resolve of a Nenets herder. Though studies are ongoing, she has also begun to shed the secrets of her short life and some clues to the fate of her kind. Her healthy, well-fed state was echoed in the record of her dental development, a gratifying confirmation for Fisher that such dental records are a faithful proxy for evaluating health on the basis of teeth alone—and thus key to investigating the causes of mammoth extinction. Analysis of her well-preserved DNA has revealed that she belonged to a distinct population of *Mammuthus primigenius* that, soon after her time, would be replaced by another population migrating to Siberia from North America. On a more intimate scale, Lyuba's intestine contained the feces of an adult mammoth, probably her mother's: evidence that mammoth calves, like their modern elephant cousins, ate their mother's feces to inoculate their guts with her microbes in preparation for digesting plants.

Finally, Lyuba's premolars and tusk revealed she had been born in the late spring and was only a month old when she died. The last layers of her tusk matched the pattern that Dan Fisher associates with accidental death: a series of even, prosperous days, coming to an abrupt end. □



Like tiny time capsules, Lyuba's teeth hold a detailed diary of her brief life. Oxygen isotopes in the dentin of her second (top) and third (above) premolars and other teeth reveal she was born in spring. By comparing her body size and degree of tusk development with that of elephants, scientists originally estimated her age at four months. But by slicing open the second premolar and analyzing its growth lines—similar to the rings in a tree—they found that only one month had passed between her birth and death.

FROM TOP: 0.6 INCHES ACROSS; 2.1 IN ACROSS

ABOVE (BOTH): IRA BLOCK



After 40,000 years asleep, witness the awakening: *Waking the Baby Mammoth*, on **National Geographic Channel**, April 26 at 9 p.m. in the U.S.

Get to know Lyuba one-on-one at ngm.com/interactive/mammoth.



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More than 100,000 people came to see Lyuba when she briefly went on display after the CT scan in Tokyo. The Field Museum in Chicago is planning an exhibition tour starring Lyuba in 2010, with assistance from the National Geographic Society.



RECIPE FOR A RESURRECTION

Bringing extinct species back to life is no longer considered science fiction. But is it a good idea?

By Tom Mueller



Each new woolly mammoth carcass to emerge from the Siberian permafrost triggers a flurry of speculation about resurrecting this Ice Age giant. Researchers have refined at least some of the tools needed to turn that hope into reality. Last November, when a team led by Teruhiko Wakayama, a reproductive biologist based in Kobe, Japan, reported it had cloned mice that had been frozen for 16 years, the scientists conjectured that the same

techniques might open the door to cloning mammoths and other extinct species preserved in permafrost. Talk of cloning surged again a few weeks later when a group at Pennsylvania State University, led by Webb Miller and Stephan C. Schuster, published 70 percent of the mammoth genome, laying out much of the basic data that might be required to make a mammoth.

"I laughed when Steven Spielberg said that cloning extinct animals was inevitable," says



Tasmanian tigers likely died out in the 1930s, but their genetic material is preserved in these pup specimens in Australia's Tasmanian Museum and Art Gallery. Scientists look to such collections as potential sources of DNA from extinct species.

sequence—in the case of mammoths, estimated to be more than 4.5 billion base pairs long—and to express this data in flesh and blood. The publication of the partial mammoth genome is a good start on the first problem, though the remaining 30 percent of the genome would have to be recovered and the entire genome resequenced several more times to weed out errors that have crept into the ancient DNA over the centuries as it degraded. Scientists would also have to package the DNA into chromosomes—and at present they don't even know how many chromosomes the mammoth had. Yet none of these tasks appears insurmountable, especially in light of recent technical advances, such as a new generation of high-speed sequencers and a simple, inexpensive technique for recovering high-quality DNA from mammoth hair. "It's a simple question of time and money, not of technology anymore," says Schuster.

Transforming this data into a woolly mammoth will be far trickier, though the existence of close living relatives, the African and Asian elephants, helps. The Penn State team used the African elephant genome as a guide to reassemble the pieces of mammoth DNA they'd recovered from hair samples. Since this ancient DNA is far too fragmented to use to create an organism, one way to make living mammoth genetic material might be to modify elephant chromosomes at each of the estimated 400,000 sites where they differ from the mammoth's, effectively rewriting an elephant's cells into a mammoth's. If researchers can figure out how mammoth DNA was organized into chromosomes, another strategy would be to synthesize the entire genome from scratch, although so far

Hendrik Poinar of McMaster University, an authority on ancient DNA who served as a scientific consultant for a film about the making of *Jurassic Park*. "But I'm not laughing anymore, at least about mammoths. This is going to happen. It's just a matter of working out the details."

As Poinar himself admits, however, the details are daunting. The two fundamental steps involved in cloning a mammoth, or any other extinct animal, are to recover its complete DNA

the largest genome to be synthesized was only a thousandth the size of the mammoth's.

Once scientists have functional mammoth chromosomes in hand, they could wrap them in a membrane to create an artificial cell nucleus. Then they could follow the approach pioneered in creating Dolly, the sheep cloned in 1996 by scientists at the Roslin Institute in Scotland: Remove the nucleus of an elephant's egg and replace it with the rebuilt mammoth nucleus, electrically stimulate the egg to trigger initial cell division into an embryo, and eventually transfer the embryo into an elephant's womb for gestation. Each of these steps has significant question

In 2008 scientists reported they had brought a piece of Tasmanian tiger DNA back to life by inserting it into a mouse embryo. A special dye revealed that the extinct DNA turned on in the forming skeleton.



COURTESY RICHARD BEHRINGER

marks of its own. No one knows, for example, just how to build a mammoth nucleus. Harvesting an elephant egg is difficult, and bringing a mammoth fetus to term in an elephant uterus is fraught with uncertainties.

Some scientists are tackling a less daunting challenge: cloning endangered or recently extinct animals. The San Diego Zoo and the Audubon Center for Research of Endangered Species in New Orleans both maintain "frozen zoos," where the DNA of a growing number of endangered species is stored in tanks of liquid nitrogen at minus 320° Fahrenheit. In 2003 scientists at Advanced Cell Technology used cells stored at the San Diego facility to successfully clone across the species barrier. They created two bantengs, an endangered Southeast Asian ox, by inserting banteng DNA into domestic cow eggs and placing the resulting embryos in cow foster-mothers. There is talk of using similar methods to clone endangered giant pandas, African bongo antelopes, and Sumatran tigers. Ultimately scientists hope to re-create extinct species like the Pyrenean ibex and the thylacine, or Tasmanian tiger.

Today the thorniest questions about cloning extinct species may be less technical than ethical. "Mammoths, like elephants, were intelligent, highly social animals," says Adrian Lister, paleontologist and mammoth expert at the Natural History Museum in London. "Cloning would give you a single animal, which would live all alone in a park, a zoo, or a lab—not in its native habitat, which no longer exists. You're basically creating a curio." Tom Gilbert, an expert in ancient DNA at Copenhagen University who with Schuster and Webb pioneered the harvesting of mammoth DNA from hair, admits that as a student of mammoths, he'd be the first to go see one trundle across a paddock. But he questions both the utility and the wisdom of cloning extinct species. "If you can do a mammoth, you can do anything else that's dead, including your grandmother. But in a world in global warming and with limited resources for research, do you really want to bring back your dead grandmother?" □

WILL A MAMMOTH WALK AGAIN?

The decoding of 70 percent of the mammoth genome in 2008 sparked new hope that the species might be brought back to life. Huge hurdles remain, but new technologies, and the close genetic match between mammoths and living elephants, suggest ways the experiment may one day be accomplished.

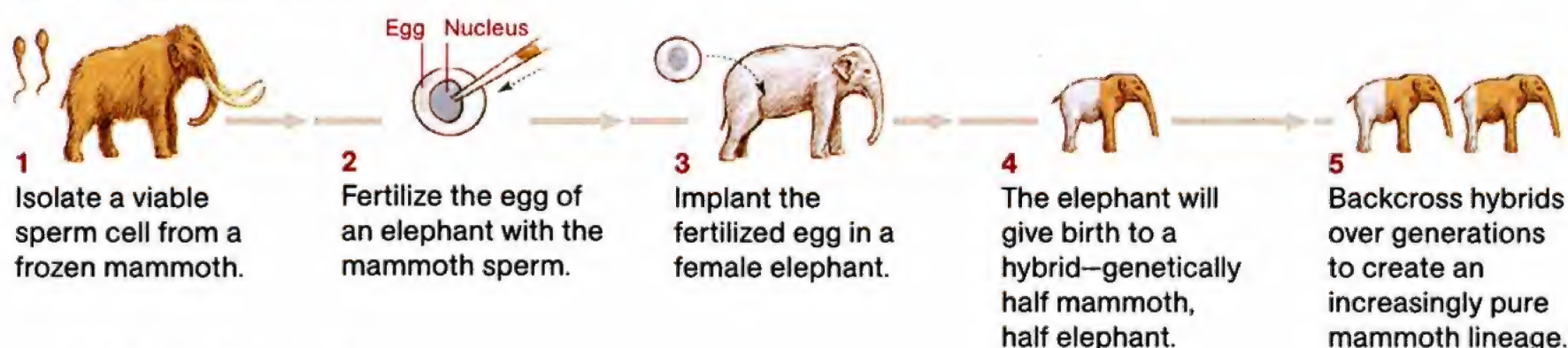
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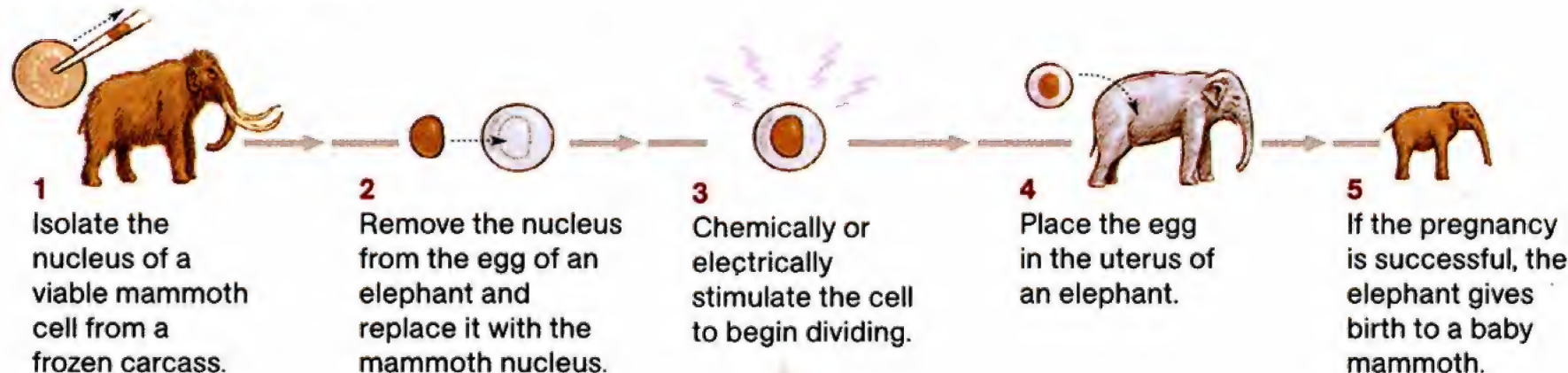
Woolly mammoth

Asian elephant

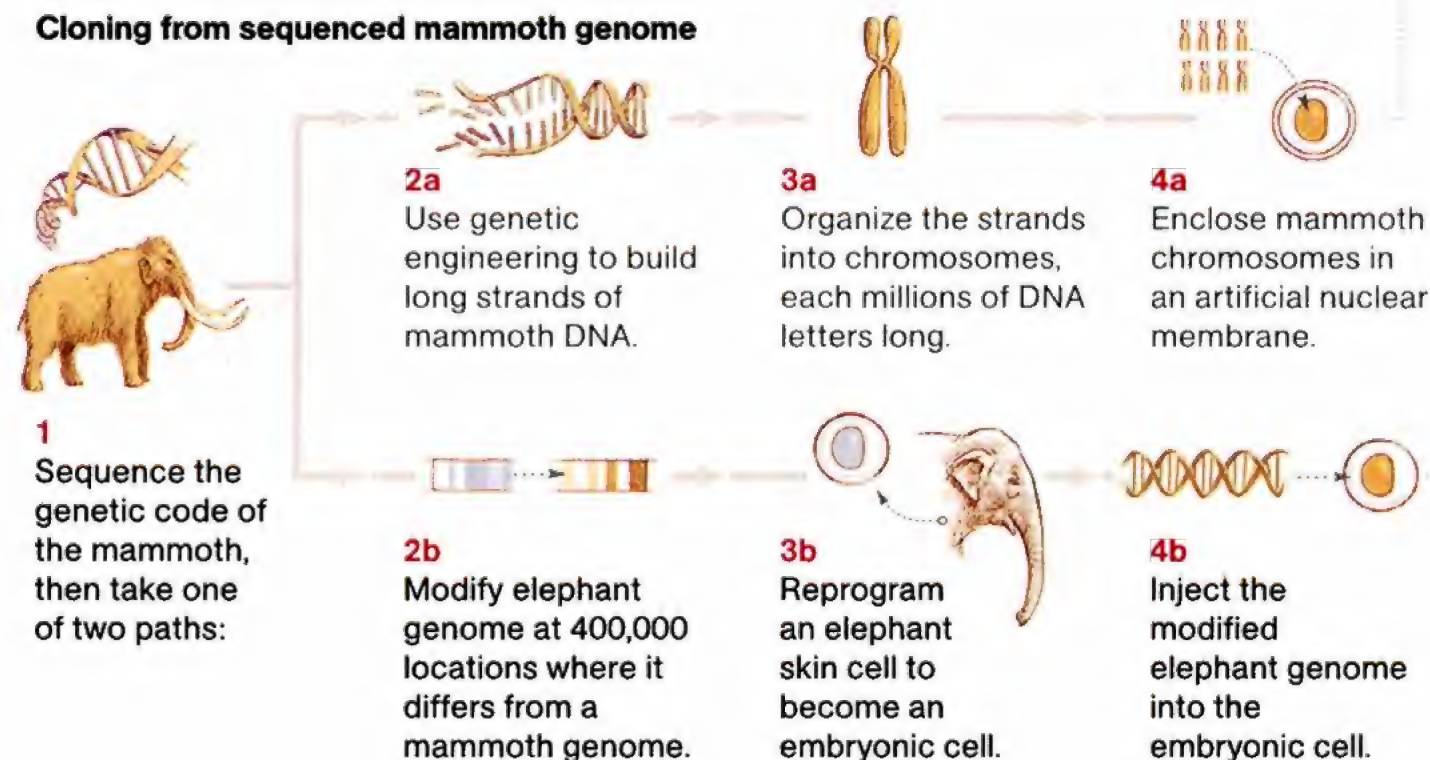
In vitro fertilization from frozen sperm



Cloning from a frozen cell




Cloning from sequenced mammoth genome



Follow the cloning steps above.

FERNANDO G. BAPTISTA, NG STAFF; ART BY KAZUHIKO SANO (TOP)
SOURCES: HENDRIK POINAR, MCMASTER UNIVERSITY; STEPHAN C. SCHUSTER, PENNSYLVANIA STATE UNIVERSITY

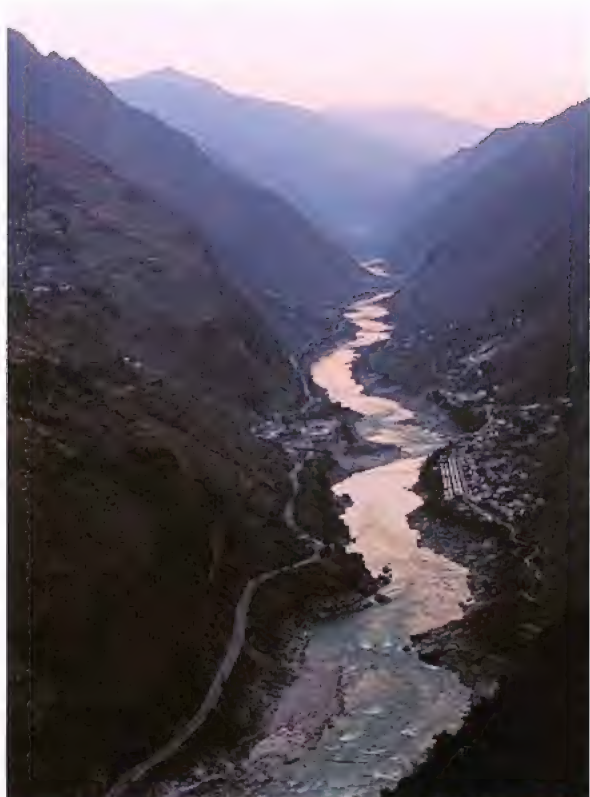


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Muscling over the Nu River's rush on a steel cable, Nan Boyi hauls a cow to market. The hard-earned sale brought this Lisu-minority villager about \$150, two-thirds the average yearly income in rural Yunnan Province.




SEARCHING — FOR — SHANGRI-LA

Two visions of the future compete
for the soul of China's western frontier.

BY MARK JENKINS
PHOTOGRAPHS BY FRITZ HOFFMANN

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A determined pilgrim climbs through a thin-air tapestry of prayer flags up to a 14,721-foot pass between Yunnan and Tibet. To circle Buddhism's sacred Mount Kawagebo, she will walk for nearly two weeks.

FLAP, AT LEFT: THE NU RIVER FLOWS SOUTHWARD THROUGH A NARROW GORGE.





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Officially sanctioned Tibetan traditions grow bigger in the city of Shangri-La. Music blares nightly from loudspeakers in Culture Square, where locals gather for folk dancing. Rings of clockwise motion echo spinning prayer wheels.



庆祝改革开放40周年 群众文化活动

乐城文化中心二期盛大开幕 为市民提供高品质文化休闲场所

乐城文化中心二期盛大开幕

售楼中心

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Once a solitary magnet for local Buddhists' attention, a white stupa on Shangri-La's airport road now faces competition. Workers scale looming billboards to hang promotions for new wines, new cars, and luxury travel.

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Perched by a blooming rapeseed field on the Nu Valley road, a farmer seeks a buyer for his berries. Level, fertile cropland is scarce here, and proposed hydropower dams would flood much of it.

A cheerful group of Chinese tourists, all from eastern cities, are pushing against an enormous Tibetan prayer wheel.

On a bus tour of China's wild west, they're having fun trying to get the giant instrument spinning. No less than 50 feet tall and 25 feet in diameter, the Fortunate Victory Prayer Wheel depicts, in bas-relief, China's 56 ethnic groups working together in fabled harmony.

Three maroon-robed monks, shorn and strong, arrive to give a hand. The tourists have been trying to push the prayer wheel counterclockwise—the wrong direction in Tibetan Buddhism. The monks reverse their energy and get the wheel twirling like a gargantuan top.

Someone's cell phone trills a Chinese pop tune. A woman in lavender tights digs into her oversize purse. A man in a suit reaches into his black leather overcoat. A girl in plaid Converse high-tops rummages in her silver backpack. But it is one of the monks who steps away from the wheel and pulls the gadget from the folds of his robe.

He shouts into the phone while staring out across the city below. There is the Paradise Hotel, a five-star colossus enclosing a swimming pool and an enormous white plastic replica of sacred Mount Kawagebo. There, sprawling in all directions, are gray concrete tenements. There, against a far hillside, is the restored 17th-century Ganden Sumtseling Monastery, a smaller but no less inspiring version of the grand Potala in Tibet, gleaming in the wood-smoke haze like an imaginary palace.

Welcome to Shangri-La.

A decade ago this was an obscure, one-horse village on the edge of the Tibetan Plateau. Today, after an extreme makeover, it's one of the hottest tourist towns in China, gateway city to the Three Parallel Rivers World Heritage site in northwestern Yunnan Province.

Ten years ago the original village was becoming a ghost town of derelict buildings and deserted dirt roads. Most residents had moved out of their traditional homes—commodious chalet-like farmhouses with stone walls and magnificent wooden beams—into more modern structures with running water and septic systems. The historic quarter they left behind seemed doomed.

Tourism saved the place. The Tibetan farmhouses were suddenly rediscovered as unique, endemic architecture that could turn a profit. Redevelopment began immediately. Water and sewer lines were buried beneath the crooked lanes. Electricity and the Internet were snaked in. The old homes were rebuilt and turned into fancy shops. New shops were constructed in the same style but with baroque facades—ornately carved dragons and swans and tigers—to attract Chinese tourists. Which they did: More than three million tourists, almost 90 percent of them Chinese, visited Shangri-La last year.

Take for instance the woman in black leather pants who steps out of a Hummer in the parking lot of the Sumtseling Monastery, hands off her little purse, and climbs up on a wildly decorated yak tended by an elaborately costumed Tibetan, sword and all. Her friends snap photos. She could as easily be a tourist mounting a horse in Deadwood, South Dakota, or standing beside a buffalo in Jackson Hole, Wyoming. Just as Native American culture has been commodified in the American West, Tibetan culture has been commercialized in China's west. In the old town, high-end shops selling faux Tibetan jewelry, knives, and furs—the spotted cat skins are actually dyed dog hides—have replaced the chickens and pigs that once inhabited the ground floors of Shangri-La's homes.

At the giant prayer wheel the tourists and monks have tired of the gilded merry-go-round

and are leaving, when an elderly Buddhist woman arrives. She's wearing a traditional wool apron, but it is filthy, as if she'd walked a great distance and performed many prostrations along her pilgrimage. A fuchsia head scarf is plaited into her graying braids. She is thumbing through 108 prayer beads while repeating in a humming whisper the holy mantra *om mani padme hum*, a prayer for compassion and enlightenment.

The old woman grabs the rail of the giant spindle and, throwing her full weight into this act of devotion, keeps the wheel turning.

UNLIKE OTHER PLACES with mythically resonant names, such as Timbuktu or Machu Picchu, Shangri-La never actually existed until now. The name comes from James Hilton's 1933 novel, *Lost Horizon*, a tale of plane-crash survivors who find their way to a utopian lamasery called Shangri-La in the wastelands of Tibet. In the book the lamasery, founded in the 18th century by a Catholic missionary named Perrault and now administered by a high lama, sits at the base of a mountain called Karakal, a fulgent pyramid of snow and rock. Home to more than 50 monks from nations around the world, all deep in spiritual studies, the lamasery is a grand repository of humanity's wisdom, embracing the best of both East and West. Midway through the novel readers discover that the high lama is actually Perrault himself. He's more than 200 years old, having been well preserved by serious study, the immersional serenity of Shangri-La, and isolation from a modern world mindlessly drifting toward holocaust.

Hilton is said to have taken his inspiration for Shangri-La in part from the writings of the eccentric botanist Joseph Rock, whose tales of exploration and adventure in remote Yunnan, Tibet, and elsewhere appeared in this magazine from 1922 to 1935. The irascible Rock led expeditions in search of exotic plants and unknown cultures. He wrote of sliding over the Mekong

Mark Jenkins is a National Geographic contributing writer. Photographer Fritz Hoffmann has been documenting change in China since 1995.

Fed by monsoon storms, three great rivers have bulldozed **staggeringly deep chasms**—twice the depth on average of the Grand Canyon.

on a bamboo zip line, of attacks by brigands, of mysterious rituals and meetings with kings. Rock's flair for the flamboyant must have captivated Hilton, a British romantic who wrote 22 novels, including *Good-bye, Mr. Chips*.

Hilton also drew from another source, one much older than the writings of Joseph Rock. Shangri-La sounds like—and almost certainly is—a thin disguise for Shambhala, the earthly paradise in Tibetan Buddhism where there is no war and no suffering, and where people live in peace and harmony through meditation and self-discipline. In Buddhist texts Shambhala is said to reside beyond the Himalaya at the base of a crystal mountain, its inhabitants untouched by the venality and avariciousness of the outside world. For Hilton, born in 1900 and witness to the devastation of World War I and the Depression, this alluring Eastern legend would have had powerful appeal.

Mix a novelist's imagination with Tibetan mythology, add a dash of Joseph Rock and a generous helping of longing, and you get a nice recipe for *Lost Horizon*. Although the novel is rarely read today, the word Shangri-La and what it symbolizes—a faraway place of beauty, spiritual replenishment, and supernatural longevity—have long been part of world pop culture.

Of course the problem with the book is the problem with all utopian narratives: It downplays the negative but no less natural afflictions of humankind, such as jealousy, lust, greed, and ambition. In the end, this makes both the book and its unifying theme, Shangri-La, seem simplistic—precisely the opposite of the modern-day city of Shangri-La, a place that could hardly be more complicated or confounding.

IN ITS PREVIOUS INCARNATION, Shangri-La was Zhongdian, a 10,000-foot-high trade-route town located just east of some of the deepest and most dramatic gorges in the world. Three great rivers—the Yangtze, the Mekong, and the Salween, separated by towering mountain

ranges and known hereabouts as the Jinsha, the Lancang, and the Nu—all sweep east of the Himalaya, then drop due south in tight parallel formation before pouring off in different directions. This was the remote region that Rock explored in the 1920s and '30s.

But much has changed since then. Large-scale commercial logging began in the 1950s. Roads were gouged into the mountains, and thousands of acres of old-growth forest were clear-cut from the sheer slopes. By the mid-1990s, more than 80 percent of the area's income came from timber operations. Then in 1998, due in part to overlogging of the Jinsha catchment, the river flooded. Nearly 4,000 people died, and millions lost their homes. In response, the Chinese government banned all commercial logging in the Three Rivers region.

Forced to retool its economy, Zhongdian turned to tourism, capitalizing on its distinctive architecture and proximity to stupendous geography. At the time Zhongdian had no airport, and it took two days on a rough road to reach the town from Kunming, the nearest major city. An airport was built in 1999, and the Kunming road was finished a year later. By 2001, revenues from the tourist industry had already surpassed what had once come from logging.

That same year, after considerable lobbying, canny local officials were given authorization from Beijing to rename their town and county Shangri-La—a marketing coup, given how many other savvy villages in Yunnan and Sichuan were vying for the famous appellation. The Fortunate Victory Prayer Wheel was erected the next year, and hotels and gift shops began sprouting like the expensive matsutake mushrooms that Tibetans pick in the summer for export to Japan.

The crowning tourist-catching achievement came in 2003 when the United Nations officially acknowledged the prodigious biodiversity of the river gorges and designated the region the Three Parallel Rivers (Continued on page 80)



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DEEP CHINA

Flanked by World Heritage landscapes more than three times the area of Grand Canyon National Park in the U.S., the Jinsha, Lancang, and Nu Rivers carve through gorges as much as two miles deep and shape China's biodiversity stronghold.

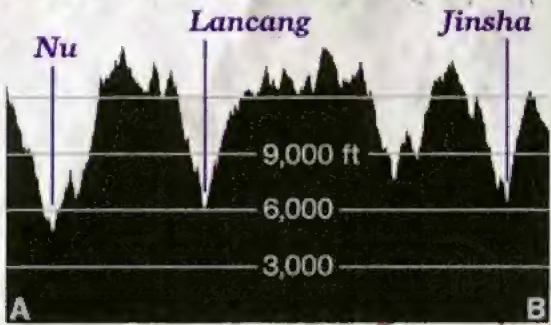
**Three Parallel Rivers
UNESCO World Heritage site**

- Protected nature reserve
- Scenic area
- Proposed dam*
- Dam under construction

*While 13 dams on the Nu were proposed in 2003, current plans reduce the number to four.

0 mi 25
0 km 25

Three Parallel Rivers Profile



MARTIN GAMACHE AND MARGUERITE B. HUNSIKER, NG STAFF
SOURCES: INTERNATIONAL RIVERS; YUNNAN PROVINCIAL
DEPARTMENT OF CONSTRUCTION





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Lush green brightens a gorge wall where warm, mineral-rich waters from hot springs tumble into the Nu River. Deep valleys between high peaks host a dramatic range of habitats, creating bastions for rare species.





Resting briefly in dense forest, Gong Qu Yi Xi walks the pilgrim path around Mount Kawagebo. Necessities bundled on his back, the 15-year-old Tibetan sets off before dawn and stops only when night shrouds the mountains.




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Lisu women bathe in thermal pools to celebrate the coming of spring. A proposed dam would drown this site, one of the valley's few remaining public baths. Developers have turned other springs into tourist resorts.





A photograph of a stream with logs and a woven basket. The stream is filled with water and has several large logs floating in it. A woven basket is visible on one of the logs. The background shows a wooden structure, possibly a house or a bridge, made of logs. The overall scene is a rural, mountainous area.

As dusk settles over isolated Wuli village, Liu Chunxing tends the log-and-hose plumbing that channels water to his family's small hydropower generator. Harnessing the stream provides electricity for some 30 families here.

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Leaving a weekly market, villagers slide themselves, baskets of food, and cartons of beer over the river on the cable and pulleys of a zip line. Once across, they'll hike for several hours up the valley walls to home.

(Continued from page 68) World Heritage site. Instantly, Shangri-La became the new hot spot for Chinese travelers willing to pull on hiking boots and experience the frontier firsthand.

Fed by monsoon storms, the three great rivers have bulldozed staggeringly deep chasms that often exceed 10,000 feet, twice the depth on average of the Grand Canyon. The World Heritage site also embraces more than a hundred peaks higher than 16,000 feet. Because of the stunning verticality, ecosystems can range from subtropical to arctic-like in the space of mere miles.

Described by the UN as the “epicenter of Chinese biodiversity,” Three Parallel Rivers has more than 6,000 vascular plant species—more than 200 types of rhododendrons, 300 species of timber trees, and some 500 medicinal plants. With such floral diversity, it follows that the fauna would also be extensive. There are at least 173 mammals—including rare species such as the clouded leopard and red goral—as well as more than 400 types of birds.

Radical topography also engendered human diversity. Separated by uncrossable rivers and soaring mountains, individual ethnic groups developed distinct languages and traditions unique to their own environments. Three Parallel Rivers has at least a dozen ethnic groups, including Tibetan, Yi, Naxi, Lisu, and Nu, comprising some 300,000 people.

World Heritage designation is meant to preserve irreplaceable environmental and cultural diversity, so it’s ironic that the Three Parallel Rivers charter doesn’t protect the rivers themselves. One reason is that much of the natural habitat along the rivers has been affected by human settlement. But excluding the rivers serves another purpose: meeting China’s desperate need for energy. Eighty percent of the country’s electrical supply is provided by coal-fired power plants. But coal is dirty energy, and air pollution endangers the health of millions of Chinese. Hydropower, which now generates

15 percent of China’s electricity, represents an obvious, and controversial, alternative. A dozen dams are planned for the Jinsha, four of which are already under construction. The Lancang has three existing dams, with two more being built, and up to nine more proposed. Only two dams have been built on the Nu, but a proposal put forward in 2003 called for 13 more. Alarmed, activists have been toiling to save the river.

“Damming the Nu has become a national debate in China,” says Yu Xiaogang, founder of Green Watershed. So far Yu, along with environmental journalists and academics, has helped block further dam construction on the Nu and reduce the number of proposed future dams from 13 to four. But given the ballooning energy needs of China and nearby countries—much of the electricity is intended for sale outside China—at least some of the proposed dams will likely be built soon.

While the nearest of the monumental gorges lies within easy reach of the tourist hotels in Shangri-La, almost none of the biological diversity of the Three Parallel Rivers region can be found near the city. If another Shangri-La exists—a place of seclusion and serenity resembling the spellbinding myth in our collective imagination—it must lie out where Rock discovered a beguiling if brutal place that Hilton transfigured into a paradise. That’s where I went looking for a truer Shangri-La.

CUTTING THROUGH SNOWDRIFTS beneath an archway of prayer flags snapping like whips, my hiking companion, Rick Kent, and I are literally blown off 16,000-foot Shu Pass, thrown from Yunnan Province across the knife-edge border into Tibet. We’re crossing from the Lancang watershed into the Nu watershed. The flat-line distance between the two rivers is 22 miles, but the landscape here is anything but flat. Mount Kawagebo, the highest mountain in Three Parallel Rivers, soars to more than 22,000 feet, its summit during this season hidden in clouds.

World Heritage designation is meant to preserve **environmental diversity**, so it's ironic that the charter doesn't protect the rivers themselves.

The two-day climb to the pass starts at 7,000 feet, where the Lancang is broad and brown with mud and the hillsides are spiked with cactus—the valley so warm that farmers are growing grapes. Every thousand feet above the river brings a new ecozone: crackling deciduous forests, yellow leaves strewn on the trail like brooches; evergreen broad-leaved forests silent as a shadow; temperate coniferous forests with pungent, almost foot-long pine needles webbed in strands of lichen; alpine meadows with green grass knifing up through snow.

Above it all, Mount Kawagebo rises out of the mist like a monster, its summit ominously loaded with cornices of snow hundreds of feet deep. Seventeen Japanese and Chinese climbers died in an avalanche there in 1991. The mountain is now closed for climbing, not because of the danger but in deference to its religious significance. Kawagebo is one of the most sacred peaks in Tibetan folklore. Every year thousands of Buddhist pilgrims circle the massif on foot on a two-week *kora*, or circular path, the purpose of which is to seek purification and thereby ensure a more propitious reincarnation.

But times are changing. We can hear one group of pilgrims—all Tibetan youths, singing and giggling—before we see them. They pass us like a circus troupe. No solemn, somber affair for these kids, a pilgrimage is a big party. One of them is waving a Chinese MP3 player, the volume turned up to a tinny blare.

Dropping continuously, the trail becomes so steep it starts to switchback every 20 feet, the path a two-foot-deep trough worn into the soft rock. Snow gives way to talus, then to trees, then to dense forest. At an overlook I peek down through a hole in the strands of gray lichen as if into another world. Thousands of feet below us, wedged in the crook of a valley beside a steep, old-growth forest, is a tiny square of brilliant green—another vision of Shangri-La.

It takes hours, descending hundreds of switchbacks, to reach the enchanted place. A

man with a load of wood on his back is waiting. He leads the way beneath a giant walnut tree, down through skittish pigs and oblivious goats, over a stone fence, along a neon barley field, to a whitewashed, fortress-like Tibetan home. Up a dirt ramp, we pull the leather thong, a little door opens, and we step into the 15th century. A shrunken woman in a red head wrap greets us with both hands, pours two cups of boiling yak butter tea, then disappears.

The floor plan is traditional Tibetan: In the center is a large, open-to-the-sky atrium, warm sunlight dropping inside. A wooden railing—set with planters of various herbs—boxes in the atrium on the main floor, keeping crawling kids from falling to the ground floor, where pigs and chickens live in splendid squalor. Up a hand-hewn ladder is the roof, a flat mud surface with the atrium cut from the middle. The roof is covered with stores of food and fodder: pine cones piled like pineapples, two varieties of corn, chestnuts spread across a plastic tarp, walnuts on another tarp, three varieties of chilies in various stages of drying, green apples in a basket, sacks of rice, slabs of pork air-drying, the carcass of what appears to be a marmot.

Grandparents, parents, kids, and an uncle all share the farmhouse. All have their tasks: the scrawny uncle carrying sacks of corn and sorting horseshoes; the young mother, baby on back, tending the stove and preparing dinner; the patriarch slowly writing something in a ledger in shaky Tibetan script. The sinewy woman who served us tea is the matriarch. She slops the hogs with a kitchen pail, dumping the contents over the railing, then goes outside, where she milks the cows and feeds the horses and churns the yak butter. Through pantomime she explains that she has pain behind her eyes and asks us for medicine. All I have is ibuprofen.

At nightfall it is pitch-dark and frosty inside the house. A terrific screeching cuts the stillness. The patriarch is turning a metal crank mounted on the wall, winding up a cable. As he locks the

Just as Native American culture has been commodified in the American West, Tibetan culture has been **commercialized** in China's west.

crank arm in place, compact fluorescent light-bulbs dangling around the house burst to life. The metal cable, it turns out, extends to a creek 400 yards from the farmhouse. There it attaches to a trough carved from a log. Turning the crank pulls the cable, which lifts the trough, sending a flow of creek water into a large wooden cask. Plugged into the base of the cask is a blue plastic pipe that carries water down to a Chinese-made micro-hydropower generator the size of a five-gallon drum.

Dinner is served. Rice with assorted dishes—pork fat in garlic sauce, yak meat with peppers, fried vegetables, glasses of homemade, throat-scalding barley wine, apples for dessert. And then the patriarch opens a carved cabinet door and clicks the remote. There's a soccer match on TV he doesn't want to miss.

The women of the household are up for hours before dawn, hauling water and wood, milking and feeding the animals. The young mother pours us yak butter tea. Her name is Snaw. She is wearing a black baseball cap embroidered with a skull and crossbones, a tattered purple sweater through which you can see her bony body, a thin, fake-fur scarf, tight jeans, and green Chinese army sneakers. Her baby in one arm, she is simultaneously breast-feeding, loading firewood into the stove, checking the rice, stirring the yak butter tea, tossing potato peels over the railing to the pigs, washing dishes, sorting peppers, and talking.

Snaw is 17. Her baby is three months old and has some indiscernible medical problem. She says her dream is to leave this place—the Shangri-La of my imagination—and go to the real town of Shangri-La. She's heard that women her age go to school there and on Saturday go shopping, walking arm in arm along the mall.

SOME YOUNG WOMEN'S DREAMS have already come true. Yang Jifang, a tall, striking 22-year-old Naxi woman, graduated from the Eastern Tibet Training Institute (ETTI) in downtown

Shangri-La. There she learned English and computer skills; she now works as a guide at the Khampa Caravan, an adventure-travel firm. She has her own apartment and goes back to her rural village every month, bringing money and medicine to her parents.

"Life for my parents in the village is very hard," she says. "There is no business, just farming."

The training institute was founded in 2004 by Ben Hillman, a professor at the Australian National University who specializes in development in western China. The institute hosts an intensive 16-week, live-in, fully funded vocational school designed to help students from rural areas bridge the gap to urban job opportunities.

"Culture is something that's constantly evolving," says Hillman, who warns me not to apply a Western sense of authenticity to the modern Shangri-La. We're sitting at the Raven café in the old town, listening to Dylan and drinking Dali beer. The Raven, a rebuilt cobbler's shop, is the kind of funky coffee bar you find in Kathmandu—carrot cake on the menu, a poster of John Coltrane on the wall. Owned by a Seattleite and a Londoner, it's operated by two independent Tibetan women.

"Economic development can rekindle interest in cultural heritage, which is inevitably reinterpreted," Hillman says. "I don't think we can judge that without reverting to some kind of elitism, where wealthy and fortunate people who can travel to remote parts of this planet want to keep things locked in a cultural zoo."

The real challenge for Shangri-La's ethnic minorities, Hillman says, is to develop skills for the modern world. "They are traditionally agropastoralists, experts at subsistence farming—growing barley, raising yaks and pigs. But these aren't the skills that most youth need today."

His students hail from disparate ethnicities—Tibetan, Bai, Lisu, Naxi, Han, Yi—but most come from dirt-poor farming households. All



Pool cues, leather jackets, and cell phones: Even young Buddhist monks from the venerable Ganden Sumtseling Monastery nearby indulge in Shangri-La's fresh temptations.

had to beg their parents to let them attend this school, a place of clean-scrubbed classrooms, dorm rooms, and a homey kitchen. None intend to return to hardscrabble farm life. The training institute is the kind of place Snaw dreams about while milking yaks in a freezing snowstorm.

Late in the afternoon several graduates of the institute sit together on a couch in the teachers' lounge, so excited to tell their stories that they can hardly contain themselves. The last to speak is Tashi Tsering, a lanky, vibrant 21-year-old with a shock of jet black hair in his face. A Tibetan, he too learned English and service industry skills at ETTI and now works as a guide, taking tourists to Tibetan towns and villages as far away as Lhasa. Conscious that he has escaped a life of drudgery, he wishes his friends back in the village could have the same opportunity he has enjoyed. "Now I can play an important role in the future!" he says.

Tsering looks over at his fellow alums with pride, then out the window at bustling Shangri-La, the construction cranes swinging over stone farmhouses, the taxis swerving around horse-drawn carts, tourist trinkets on sale next to great slabs of yak meat. His eyes follow a plane descending into the Shangri-La airport.


We can't see it from here, but in the center of the first intersection leaving the airport stands a large white stupa, a sacred Tibetan monument that Buddhists walk around clockwise, the same direction a prayer wheel spins. But cars negotiating the intersection must circle the stupa counterclockwise. Consequently, Buddhist tradition sends women bent beneath giant loads of cornstalks, heading home to feed their pigs, and men herding yaks as they have for centuries, straight into the paths of oncoming busloads of tourists. There have been collisions, but somehow it's working. □

UP ON THE ROOF

A lofty idea is blossoming in cities around the world,
where acres of potential green space lie overhead.

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A garland of nature crowns Chicago's City Hall, softening the hard edges of a town famous for steel and stone—and lowering summer temperatures on the roof. Inspired by a worldwide movement, Mayor Richard Daley has made Chicago North America's leading "green roofs" city.



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A Manhattan apartment building poses as a country cottage—a retreat former condo developer David Puchkoff built for his family. A verdant roof absorbs rain, reducing runoff, so it's also an environmental gift to New York City, where flooded sewers foul the Hudson River after downpours.





By Verlyn Klinkenborg

Photographs by

Diane Cook and Len Jenshel

If buildings sprang up suddenly out of the ground like mushrooms, their rooftops would be covered with a layer of soil and plants.

That's not how humans build, of course. Instead we scrape away the earth, erect the structure itself, and cap it with a rainproof, presumably forgettable, roof. It's tempting to say that the roofscape of every city on this planet is a man-made desert, except that a desert is a living habitat. The truth is harsher. The urban roofscape is a little like hell—a lifeless place of bituminous surfaces, violent temperature contrasts, bitter winds, and an antipathy to water.

But step out through a hatch onto the roof of the Vancouver Public Library at Library Square—nine stories above downtown—and you'll find yourself in a prairie, not an asphalt wasteland. Sinuous bands of fescues stream across the roof, planted not in flats or containers but into a special mix of soil on the roof. It's a grassland in the sky. At ground level, this 20,000-square-foot garden—created in 1995 by landscape architect Cornelia H. Oberlander—would be striking enough. High above Vancouver, the effect is almost disorienting. When we go to the rooftops in cities, it's usually to look out at the view. On top of the library, however, I can't help feeling that I'm standing *on* the view—this unexpected thicket of green, blue, and brown grasses in the midst of so much glass and steel and concrete.

Living roofs aren't new. They were common among sod houses on the American prairie, and roofs of turf can still be found on log houses and sheds in northern Europe. But in recent

decades, architects, builders, and city planners all across the planet have begun turning to green roofs not for their beauty—almost an afterthought—but for their practicality, their ability to mitigate the environmental extremes common on conventional roofs.

Across town from the library, the Vancouver Convention Centre is getting a new living roof. Just across the street there is a chef's garden on the roof of the Fairmont Waterfront hotel. Across town in another direction, green roofs will go up on an Olympic village being built for the 2010 Winter Olympics. To stand on a green roof in Vancouver—or Chicago or Stuttgart or Singapore or Tokyo—is to glimpse how different the roofscapes of our cities might look and to wonder, Why haven't we always built this way?

Technology is only partly the reason. Waterproof membranes now make it easier to design green-roof systems that capture water for irrigation, allow drainage, support the growing medium, and resist the invasion of roots. In some places, such as Portland, Oregon, builders are encouraged to use living roofs by fee reductions and other incentives. In others—such as Germany, Switzerland, and Austria—living roofs are required by law on roofs of suitable pitch.

And, increasingly, researchers such as Maureen Connelly—who runs a green-roof lab at the British Columbia Institute of Technology—are studying the practical benefits green roofs offer, helping quantify how they perform and providing an accurate measure of their ability to reduce storm-water runoff, increase energy efficiency, and enhance the urban soundscape. There is beginning to be a critical mass of green roofs around the world, each one an experiment in itself.

Walking paths and conical skylights share the grassy roof of the Art and Exhibition Hall in Bonn, Germany. With government aid, Germans led the development of modern green roofs in the 1960s. Today many cities offer incentives for their use.

Another factor driving the spread of green roofs is our changing idea of the city. It's no longer wise or practical or, for that matter, ethical, to think of the city as the antithesis of nature. Finding ways to naturalize cities—even as nature itself becomes more urbanized—will make them more livable, and not only for humans.

Living roofs remind us what a moderating force natural biological systems are. During the summer, daytime temperatures on conventional asphalt rooftops can be almost unbelievably high, peaking above 150°F and contributing to the overall urban heat-island effect—the tendency of cities to be warmer than the surrounding region. On green roofs the soil mixture and vegetation act as insulation, and temperatures fluctuate only mildly—hardly more than they would in a park or garden—reducing heating and cooling costs in the buildings below them by as much as 20 percent.

When rain falls on a conventional roof, it sheets off the city's artificial cliffs and floods down its artificial canyons into storm drains—unabsorbed, unfiltered, and nearly undeterred. A living roof works the way a meadow does, absorbing water, filtering it, slowing it down, even storing some of it for later use. That ultimately helps reduce the threat of sewer overflows, extends the life of a city's drain system, and returns cleaner water to the surrounding watershed. London, for example, is already planning for a future that may well see more street flooding, and the city is considering how living roofs could moderate the threat.

Above all, living roofs are habitable. They recapture what is now essentially negative space within the city and turn it into a chain of rooftop islands that connect with the countryside at large. Species large and small—ants, spiders, beetles, lapwings, plovers, crows—have taken up occupancy on living roofs. The list includes Britain's black redstarts, a bird that colonizes the rubble of abandoned industrial sites, a habitat

being lost to redevelopment. The solution fostered by Dusty Gedge, a British wildlife consultant and a driving force behind green roofs in the United Kingdom, is to create living rooftop habitat out of the same rubble.

And it's not just a matter of making new or replacing existing habitat. In Zürich, Switzerland, the 95-year-old living roof of a water-filtration system serves as a refuge for nine species of native orchids eradicated from the surrounding countryside when their meadow habitat was converted to cropland.

Proponents of living roofs argue that they have met most, if not all, of the technical challenges involved in grafting a biological layer onto the top of buildings of almost any scale: everything from a vegetable stand or bus stop to the ten-acre roof of Ford's truck plant in Dearborn, Michigan. While the average cost of installing a green roof can run two or three times more than a conventional roof, it's likely to be cheaper in the long run, thanks largely to energy savings. Vegetation also shields the roof from ultraviolet radiation, extending its life. And it requires a different kind of care, akin to low-maintenance gardening.

There are still philosophical challenges to be met, many of them having to do with the very idea of what a roof should be and how it should perform. Clients tend to want roofs that are easy to maintain and are uniformly green year-round, perpetual lawns in the sky, not seasonal grasslands. Builders and architects tend to want interchangeable, standardized, universal solutions, the kind of green-roof systems now being offered by some of the big corporate players in the living-roofs industry.

A living roof, though, is not just a biological alternative to a dead roof. It requires a different way of thinking altogether. A standardized green roof such as a carpet of sedums is better than a conventional roof, but it's possible to build living roofs that are even more environmentally beneficial—locally grown, so to speak. The goal for some researchers now is to find ways to build living roofs that are ecologically and socially sound in every respect: low in

Verlyn Klinkenborg is a frequent contributor. Diane Cook and Len Jenshel specialize in landscape photography. All three have no fear of heights.

environmental costs and available to as many people as possible.

Stephan Brenneisen, a Swiss scientist and a strong advocate for the biodiversity potential of living roofs, says simply, “I have to find easy, cheap solutions using materials that come from the region.” That means less reliance on plastics and other energy-intensive materials between the roof structure and the plants themselves. What matters isn’t only whether living roofs work. It’s how to make them work in the most sustainable way, using the least energy while creating the greatest benefit for the human and nonhuman habitat.

Last fall, I climbed onto the roof of the 15-story Portland Building in downtown Portland, Oregon. My guide was Tom Liptan, the city’s Ecoroof Program Manager and a self-confessed storm-water nerd, who began his experiments with green roofs by building one on his own garage in 1996. We walked to the parapet across plantings of sedums and fescues and looked down at the roof of Portland’s city hall several stories below us. It has a conventional black tar roof, the kind of roof we have taken for granted for decades. But as part of Portland’s Grey to Green project—a plan for sustainable storm-water management—that building will soon be retrofitted with a living roof. “The employees want it,” Liptan said.

In the history of that municipal building, how often had the people who worked there ever thought about that black tar roof looming over their heads? Once the living roof is completed, they may visit it only rarely, but they won’t forget that it’s there, adding habitat to the city center, filtering the rain, moderating temperatures. It reminded me of something Stephan Brenneisen said: “People feel happier in a building where we’ve given something back to nature.”

Think of the millions of acres of unnatural rooftops around the globe. And now imagine returning some of that enormous human footprint to nature—creating green spaces where there was once only asphalt and gravel. If a certain sum of human happiness is the by-product, who’s to complain? □

INSIDE A LIVING ROOF

A green roof on a commercial building is typically composed of these essential layers.

Vegetation

Water-storing plants such as sedums drink in rain that would otherwise run off a traditional flat roof.

Growing medium

Natural soil weighs too much when waterlogged, so green-roof architects use a soil composite.

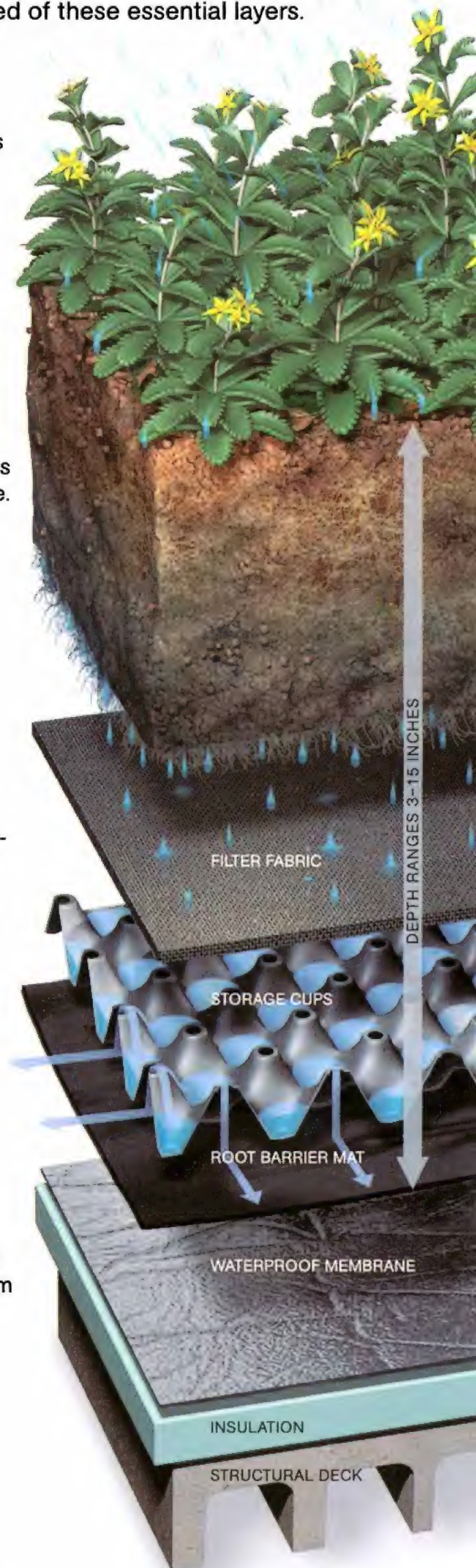
Drainage

Excess rainwater filters into a layer of storage cups or pebbles before overflowing into a drain.

During dry periods, this stored water is drawn back up to the roots.

Support

A root barrier and waterproof membrane separate the living-roof system from the insulated building below.



MARIEL FURLONG, NG STAFF
ART BY DON FOLEY
SOURCE: BARBARA DEUTSCH



Hardy sedums, insects, and birds rule the roof at a hospital in Basel, Switzerland, where foliage is mandatory on new flat roofs. "If we steal the ground for a building," says International Green Roof Association director Wolfgang Ansel, "we can give it back to nature on the roof."





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A bus shelter in downtown San Francisco (above) and a shed at the Oregon Garden in Silverton, Oregon (right), support tiny living roofs. They're intended to plant a seed in the minds of Americans. Diane Loviglio, who planned the bus shelter roof, hopes ordinary passersby will see "a viable home-improvement idea." The sustainable-design activist wanted to showcase the green-roof idea, less familiar in the U.S. than in much of Europe, "at street level," she says, "so people don't have to tour a giant industrial building to understand it."





The windows of these traditional London row houses once opened onto a decrepit sausage factory. Now residents face a wildflower meadow blooming on top of architect Justin Bere's new home. Insulation provided by the green roof helps make Bere's solar-powered house energy efficient.

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Wasted space in the modern metropolis may become productive “farmland” thanks to advances in waterproofing green roofs. Some of the rice used to brew Japan’s popular Hakutsuru sake grows atop the company’s Tokyo office (above). A chef at Vancouver’s Fairmont Waterfront hotel harvests apples ripening among skyscrapers. Hotel accountants say the roof garden produces fruits, vegetables, herbs, and honey worth about \$16,000 annually.



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It looks like a prehistoric ruin overgrown with ferns, but it may be the next step in foliage-based architecture. The Vancouver Aquarium's Living Wall varies the classic vine-covered trellis with movable vertical planter boxes and built-in irrigation, a design adaptable to many settings.





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In the heartland of American industry—Dearborn, Michigan, where Henry Ford revolutionized manufacturing—nature makes a comeback on one of the world's largest green factory roofs (above). Ford Motor Company installed sedums on the 10.4-acre expanse to reduce runoff from the site. New York's Empire State Building gleams in the windows of architectural firm Cook + Fox (right). Specialists in green buildings, the designers wanted their own space to reflect the fact that more plants in more places make for more livable cities.



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ARCTIC LANDGRAB

As rising temperatures melt the polar ice cap, five countries race to map their claims to a new energy frontier. The stakes are huge. Nearly a quarter of the world's undiscovered oil and gas may lie beneath the seabed of this vast wilderness.

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Denmark and Sweden hired a Russian icebreaker to help map the Arctic seafloor around Greenland.

BJÖRN ERIKSSON



THE OFFICE OF ARTUR CHILINGAROV, the bearded polar explorer and anointed Hero of the Russian Federation, is at the end of a long hall in the Duma, Russia's parliament, where he is deputy speaker. Its entrance is guarded by a poster of a nuclear icebreaker, the *Yamal*, a 492-foot monster with rows of painted-on fangs, and inside is a knee-high wooden penguin and two chicks, a pair of carved walrus tusks, and eight miniature porcelain polar bears—an iconography of the Arctic and Antarctic. On a wall is a portrait of

Vladimir Putin. Chilingarov sits in a leather chair in a dark suit with the Hero's gold star pinned to his breast, and next to him sits a four-foot-high globe, normal in every way but one. It has been spun off its axis, reoriented such that both Poles are visible: the Earth turned on its side.

It is winter in Moscow, three months after Chilingarov planted a Russian flag on the seafloor at the North Pole, an apparent landgrab that created a diplomatic row and a flurry of global headlines. Now he is campaigning for an election in which his party—Putin's party—will soon trounce its closest rival by a six-to-one

margin. He is a busy man, and he skips the niceties when I sit down. "It took us seven days and seven nights to reach the North Pole," he says. "The ice was heavy. It was not a simple task." Near the Pole, Chilingarov's ships found an opening in the ice, and in went two submarines, *Mir I* and *Mir II*. Chilingarov was in the first one. His goal, the true North Pole, was 14,000 feet below.

"It was dark, very dark," he says of the descent. "Of course it was risky. Of course we were scared." He and fellow parliamentarian Vladimir Gruzdev, a businessman who had paid half a million dollars for his berth, peered out the portholes. *Mir II*, which had one more paying adventurer, a Swedish businessman, and an Australian tour operator, Mike McDowell, followed. The descent was to take nearly three hours, the return to the surface that long again. Meanwhile, the ice pack would be drifting. If they could not find the opening, they would be stuck. "The depressing thing," Chilingarov tells me, "was knowing no one could come rescue us." Just after midday *Mir I* touched down on the flat, fine clay of the seabed. The sub scraped up samples of ocean floor, then moved to the Pole itself, where its robotic arm firmly planted a titanium Russian flag in the muck.

"Why did we place it? Well, anytime a country wins something, it installs its flag," he says. Many countries' flags are planted on the surface ice at the North Pole, he points out. At the South Pole there are flags. On top of Mount Everest there are flags. "The Americans even put one on the moon," Chilingarov says. He pulls out a photo of the titanium flag and robotic arm,



In three decades the retreat of sea ice has freed more than a million square miles of ocean for research and commerce.

A photograph showing a Russian flag being planted on the Arctic Ocean floor. The flag is attached to a mechanical arm of a submersible. The background is dark and murky, typical of deep-sea photography.

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On the Arctic Ocean floor a Russian submersible plants a flag at the North Pole in August 2007. The feat had no legal significance, but called attention to the country's large territorial claim.

dramatically signs it with a black marker, and hands it to me. "This is one of the world's greatest geographical achievements," he proclaims. "I'm proud the Russian flag is there." Then he stabs at the photo with his finger, pointing out empty space on the seabed. "Look here, and here, and here, and here," he says. "There is plenty of room for other nations' flags."

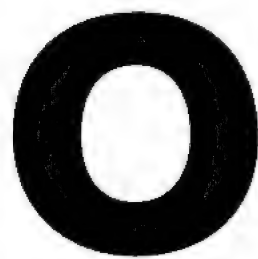
Chilingarov mentions that the expedition, widely believed to be an official act of the Kremlin, was privately funded; Putin, far from ordering him to the Pole, had initially cautioned that the dive was too dangerous. A patriot and a politician, well aware his feat made him a national hero, Chilingarov glosses over other little-known details: that the idea originated not with him but with three foreigners—McDowell and two Americans—in 1997, that he joined the team less than a year before the 2007 dive, that McDowell's company had previously been offering a *Mir* dive to the "real North Pole" to anyone with a spare \$95,000, and that the seabed samples they gathered were redundant, of questionable utility to science.

The submersibles' return was harrowing—following *Mir I* up from the seabed, *Mir II* searched for an hour and a half before finding the ice opening—but the drama of the dive was soon drowned out by the supposed politics of it. More than 40 journalists were waiting aboard the surface vessels, and they quickly filed their reports: "Russia Claims the North Pole!" Chilingarov willingly stoked nationalist flames. "The Arctic," he said at a press conference, "has always been Russian."

The dive soon became something it had scarcely been: an act of expansionism, not exploration—of geopolitics rather than glorified tourism. Observers seemed ready to believe that the Arctic's future would be decided by flags and warships, belligerence and brinkmanship. Chilingarov's triumph was denounced by Canada, condemned by the Danes, snorted at by the U.S. State Department. Overnight, he became the bearded face of the bitter polar land rush. So one can be forgiven for thinking that this story—the real story of the race for the Arctic—is about Chilingarov. It is not.

This is a story about the changing Arctic, but not only in the ways we expect. The changes most important to its future may be those from millions of years in its past, from times between the Triassic and early Tertiary, when the major basins in the Arctic were just being formed. Pieces of the supercontinent Pangaea were drifting apart, and at times greenhouse gases warmed the world to far hotter than it is today. One might say that parts of the Arctic were, for a time, almost tropical—to some degree because temperatures were higher globally, but more so because parts of the Arctic have not always been in the Arctic: Some drifted north, over geologic time, from warmer latitudes. The creation of oil and gas deposits requires the right mix of organic material, heat, rock, pressure, and passage of time—and it may be hard to look at the Arctic today and imagine that it ever had enough organic life, enough heat. But for geologists, it is hard to imagine that it did not.

Now the floor of the Arctic Ocean appears to be rich in petroleum—home, according to some estimates, to nearly a quarter of the world's undiscovered supply. Sea ice is melting drastically, opening the sea to shipping and the seafloor to mineral exploration. And that seafloor is being eyed by the five countries bordering it—Canada, Denmark (which controls Greenland), Norway, Russia, and the U.S.—all hoping to claim a piece.



N A DREARY THURSDAY EXACTLY two weeks after Chilingarov's flag planting, the oceanographer leading the United States' Arctic effort sits in a Mexican restaurant

in Barrow, Alaska, the northernmost town in North America. It is a strange place to be eating chips and salsa, and it is a strange time to be Larry Mayer, a University of New Hampshire professor who is one of the world's few experts in what it takes to claim the ocean floor. Until recently, his task has been obscure; now, thanks

to Chilingarov, journalists are calling daily, and foreign governments are watching. Assembled in the restaurant are 21 others—18 scientists, two guys from the State Department, and me—and tomorrow we begin a month-long survey of what may someday become the American Arctic. The *Healy*, the newest of the U.S. Coast Guard's three aging polar icebreakers, is just offshore, and we will be shuttled to it, three at a time, in a rented helicopter. Before we go, Mayer has a request, one that acknowledges how different things are this year: "No photos of American flags," he says. Everybody laughs. "No, I'm serious," he says. "If a picture gets out in the press, we've got big problems."

For all the talk of conflict in the Arctic, there is broad agreement among northern nations, Russia included, on how to claim a piece of it: You map it. Maps matter because the shape and geology of the seafloor matter, and the shape and geology of the seafloor matter thanks to an article in the 1994 UN Convention on the Law of the Sea, a playbook for partition that has been ratified by 156 countries. (Because of obstructionism by a few UN-wary senators, the U.S. is not yet among them, but it is acting as if it is.) Under the treaty, if a state wants to grow its maritime boundaries past the customary 200 nautical miles, it must prove that the ocean bottom is continental in origin—part of its same landmass, only underwater. Political questions can have scientific answers. So politicians have turned to scientists—oceanographers like Mayer for the seafloor's shape and seismic surveyors for its underlying geology—to build their case. Only Norway has a Law of the Sea submission under active review; the U.S., Canada, Denmark, and Russia are still busy mapping.

Since 2003 Mayer's State Department-directed missions have been charting around the Chukchi Plateau, an undersea ridge that extends nearly 600 miles north of Barrow. His job, he says, is simply to discover what lies beneath the world's least explored ocean; politicians can squabble over what these discoveries mean. The oceanographer's cliché is that we know more about the surface of the moon than about the seafloor,

McKenzie Funk's book about climate change, Best Laid Plans, will be published by Penguin Press. This is his first story for National Geographic.

The race for the Arctic may be about oil, but it is about the oil that governments hope is there, not the oil they know is there.

and this is especially true in the Arctic. The first digital chart of the entire Arctic Ocean was released only in 2000, and coverage of the central ocean remains spotty, though it's constantly revised, partly with data from satellites at a thousandth of the resolution of onshore maps. To truly know the seabed's shape, scientists must measure the ocean's depth at various points. Until recently, this higher-resolution data, known as bathymetry, came only from Cold War-era submarine tracks—pencil lines across the polar expanse, often dangerously imprecise. For Mayer, the blanks in the charts are an obsession. If it is nationalism that drives him, rather than pure love of discovery, he hides it well.

For four days and 500 miles, in calm seas mostly free of ice, the *Healy* cruises north from Barrow to almost 80 degrees. The ship is 4,200 square feet and as stable as solid ground, pervaded by the low hum of its churning engines. I share a stateroom with 26-year-old Barrow native Jimmy Jones Olemaun, an Inupiat observer on board to make sure we do no harm to mammal life. He spends much of his time on the bridge scanning the sea with binoculars, or in the science party's lounge checking his MySpace account. Whenever I leave our room, he turns the thermostat down.

The main lab is near the tail of the ship, just below the waterline and below the empty helicopter hangar where Bronx-born Mayer schools younger scientists on the basketball court. Most researchers have eight-hour lab shifts, but Mayer's is from 9 p.m. to 9 a.m.—and he always seems to be there by day too. He is a workaholic, famous for eating his meals standing up. The son of an air-conditioner technician, he was an A/V monitor during elementary school, got his scuba license in high school, and was a finalist to be a NASA astronaut after graduate school. He has spent five of the past 30 years at sea. Late at night he turns up his Celtic music and taps his loafers to it, and he excitedly flies through 3-D maps of the seafloor, Google Earth-style, in a computer program he helped create. Sometimes rather than return to his stateroom, he naps on the floor.

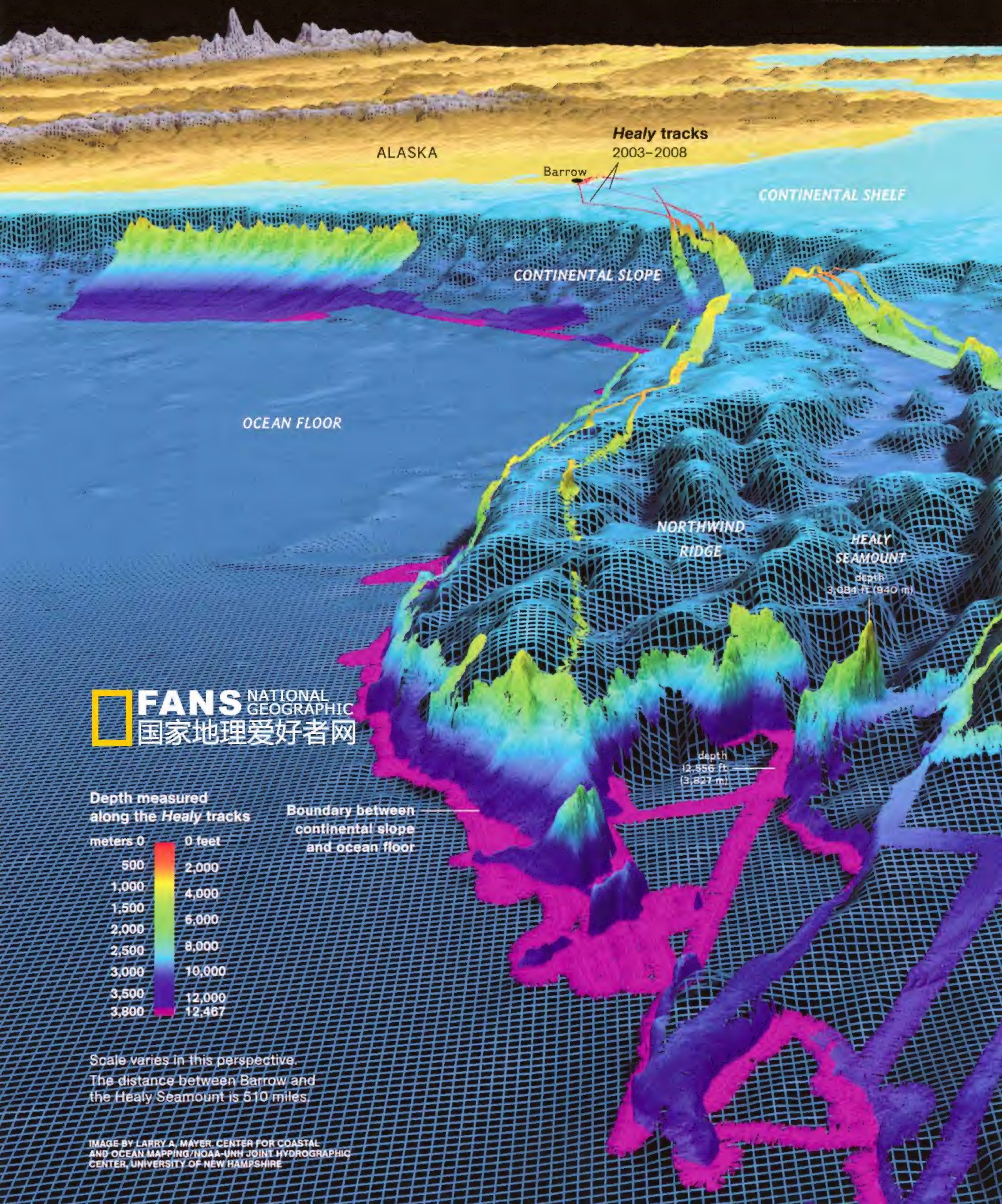
The hub of mapping activity, usually staffed by a junior scientist, is a jury-rigged wall of 11 screens—two laptops, eight PC monitors, and one closed-circuit TV—that show everything from wind speed to ocean salinity to sediment thickness. The most important monitor has jumpy green lines expanding, contracting, and shifting shape: pings, or sound waves, from the multibeam sonar embedded in the ship's hull. Mayer determines the contours of the seabed by how long it takes them to bounce back. The multibeam covers a 110-degree swath of ocean floor: some 60,000 pings an hour, as many as were available for the entire Arctic before Mayer's effort began. It is a paintbrush rather than a pencil. We watch the Chukchi Plateau rise beneath us on the monitors, the sonar overlaying the charts in real time, as if spraying on a strip of high-resolution data. Currently we are tracing the edge of the Chukchi Plateau, where continental shelf meets deep-ocean plain—the “foot of the slope,” a key detail for Law of the Sea claims. In 2003 the multibeam helped Mayer map an unknown 10,000-foot underwater mountain, which he christened Healy Seamount.

While Mayer focuses on bathymetry, other Arctic countries are first gathering seismic data, using air guns or explosives to send out shock waves that penetrate the seabed and reveal its structure. Canada and Denmark have spent millions building a geologic case that the Lomonosov Ridge—the undersea mountain range that bisects the Arctic Ocean, Russia's declared stepladder to the North Pole in a 2001 claim—is in fact connected to their side of the Arctic. (Because America's claim will rely on features that appear not to extend past the 86th parallel, it has no real shot at the Pole. Nor does Norway.) A spring 2006 Canadian-Danish survey of the Lomonosov featured camps on the ice, 970-pound (Continued on page 118)

Exploring north of Alaska in several trips, the *Healy* used multibeam sonar to map the Northwind Ridge and beyond. This and other continental formations under the Arctic Ocean may allow the U.S. to claim hundreds of thousands of square miles of additional territory.

THIS VIEW IS FROM THE NORTH LOOKING SOUTH.

UNITED STATES



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Depth measured
along the *Healy* tracks

| meters | 0 | 500 | 1,000 | 1,500 | 2,000 | 2,500 | 3,000 | 3,500 | 3,800 |
|--------|-------|-------|-------|-------|--------|--------|--------|-------|-------|
| 0 feet | 2,000 | 4,000 | 6,000 | 8,000 | 10,000 | 12,000 | 12,467 | | |

IMAGE BY LARRY A. MAYER, CENTER FOR COASTAL
AND OCEAN MAPPING/NOAA-UNH JOINT HYDROGRAPHIC
CENTER, UNIVERSITY OF NEW HAMPSHIRE

Bering Strait

RUSSIA

C h u k c h i
S e a

WRANGEL ISLAND (RUSSIA)

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CHUKCHI
PLAIN

CHUKCHI
PLATEAU

A R C T I C
O C E A N

PETROLEUM RICHES

Energy companies are leasing blocks, drilling test wells, and producing oil and gas in areas that the Arctic countries already control. When successful claims expand those countries' territories northward, new wells may further tap the deposits that began to form in this ocean more than 100 million years ago. An estimated 90 billion barrels of oil and 1,670 trillion cubic feet of natural gas may yet be discovered above the Arctic Circle, mostly offshore.

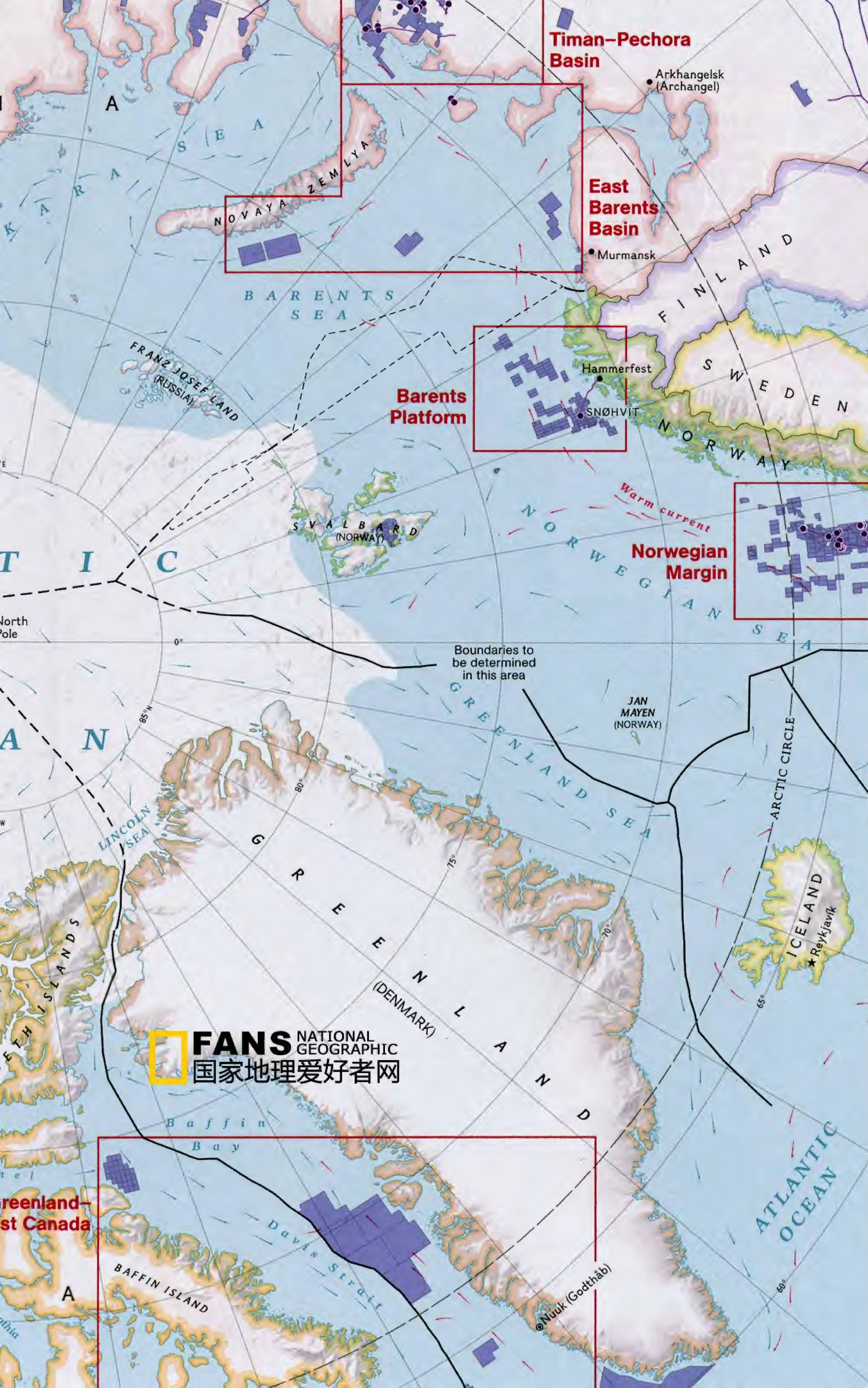
- Leased area
- Pipeline
- Well
- Oil and gas region

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Winds and currents affect the shape of the ice cap. Ice is pushed from Eurasia toward Canada, down the east coast of Greenland, and eventually into the Atlantic.

Sea-ice extent at the end of summer 2008 was the second smallest on record. Regional weather conditions contributed to a slightly smaller ice cap in summer 2007.




More than 400 oil and gas fields have already been discovered within the Arctic Circle.



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CLAIMS TAKE SHAPE

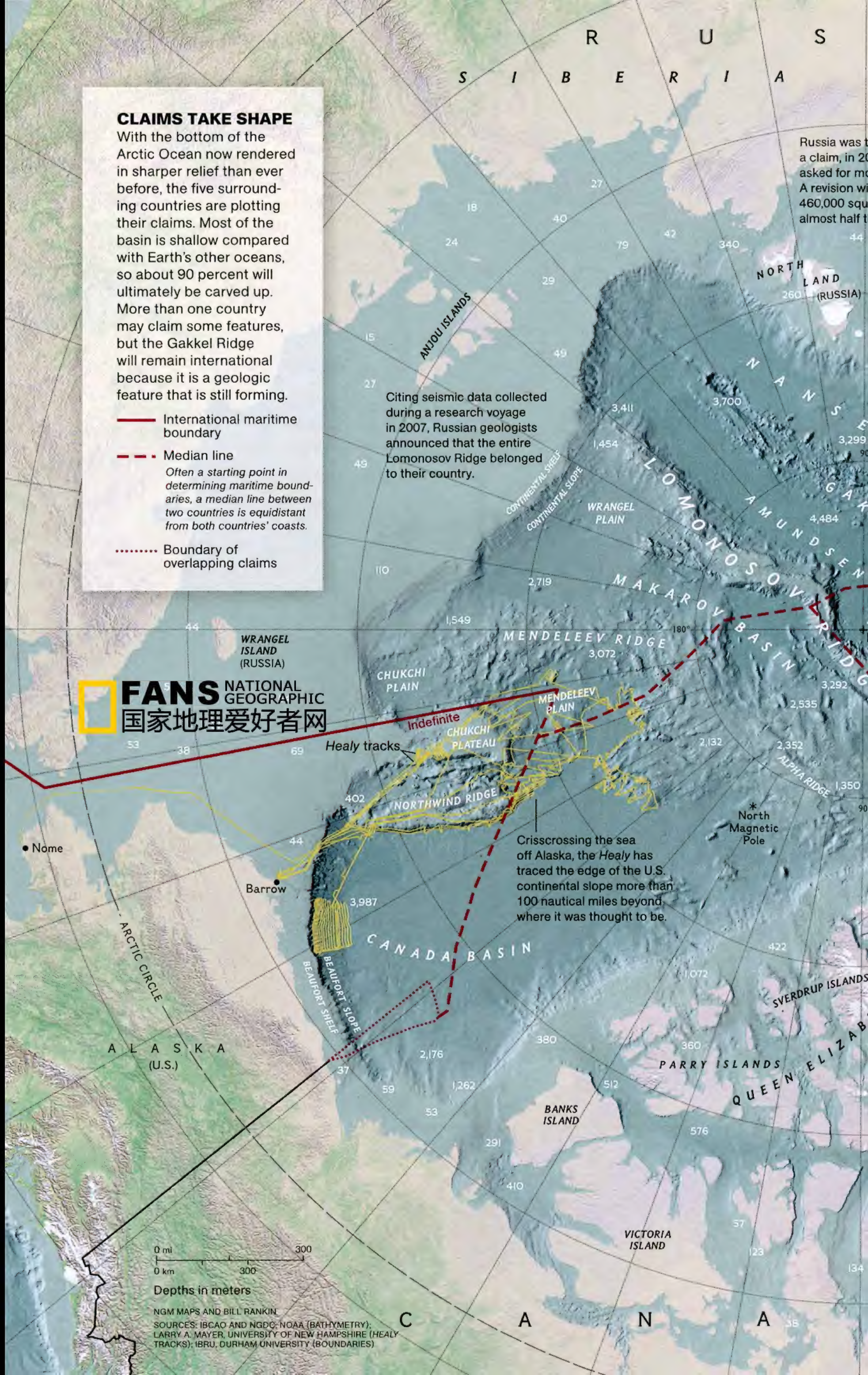
With the bottom of the Arctic Ocean now rendered in sharper relief than ever before, the five surrounding countries are plotting their claims. Most of the basin is shallow compared with Earth's other oceans, so about 90 percent will ultimately be carved up. More than one country may claim some features, but the Gakkel Ridge will remain international because it is a geologic feature that is still forming.

-  International maritime boundary
-  Median line
Often a starting point in determining maritime boundaries, a median line between two countries is equidistant from both countries' coasts.
-  Boundary of overlapping claims

Citing seismic data collected during a research voyage in 2007, Russian geologists announced that the entire Lomonosov Ridge belonged to their country.

Russia was the first to make a claim, in 2001. It asked for more than 1.2 million sq km. A revision was made in 2004, adding 460,000 sq km, almost half the original claim.

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the first to file
2001, but was
no evidence.
likely cover
are miles,
the Arctic Basin.



Norway presented a claim
in 2006. Arctic wells could
become major sources of
oil and gas bound for China
if the summer melt opens
a reliable passage for ships.

Spitsbergen
Bank

Molloy Hole
(Arctic Ocean's
deepest point)

Boundaries to
be determined
in this area

Though they disagree about
the ownership of tiny Hans
Island, Canada and Denmark
are working together to include
parts of the Lomonosov Ridge
in their separate claims.

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STAKING CLAIMS TO THE ARCTIC OCEAN

RULES OF THE GAME Each country now has sovereign rights in and under its own waters and a broad mandate to manage the resources, both living and nonliving, in its exclusive economic zone. When a country extends its defined continental shelf farther from its coast, that assures access to minerals on or beneath the seabed there. Current disputes, and any arising from new claims, will be sorted out by the countries involved.



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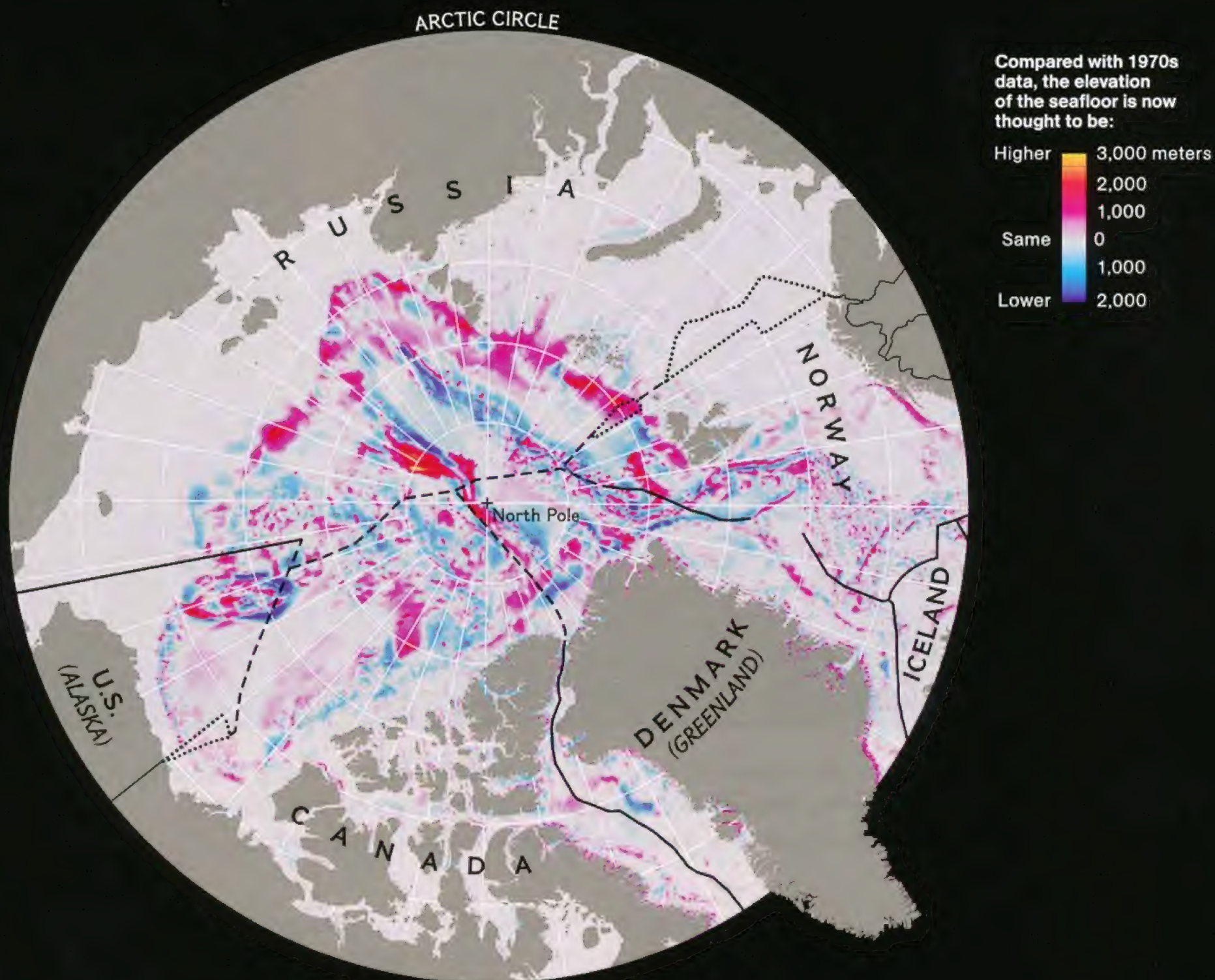
- Exclusive economic zone and territorial sea
- Unclaimed or unclaimable seabed
- Continental shelf claim
- Potential continental shelf claim
- Overlapping claims
- Internal waters

- International maritime boundary
- Median line
Often a starting point in determining maritime boundaries, a median line between two countries is equidistant from both countries' coasts.

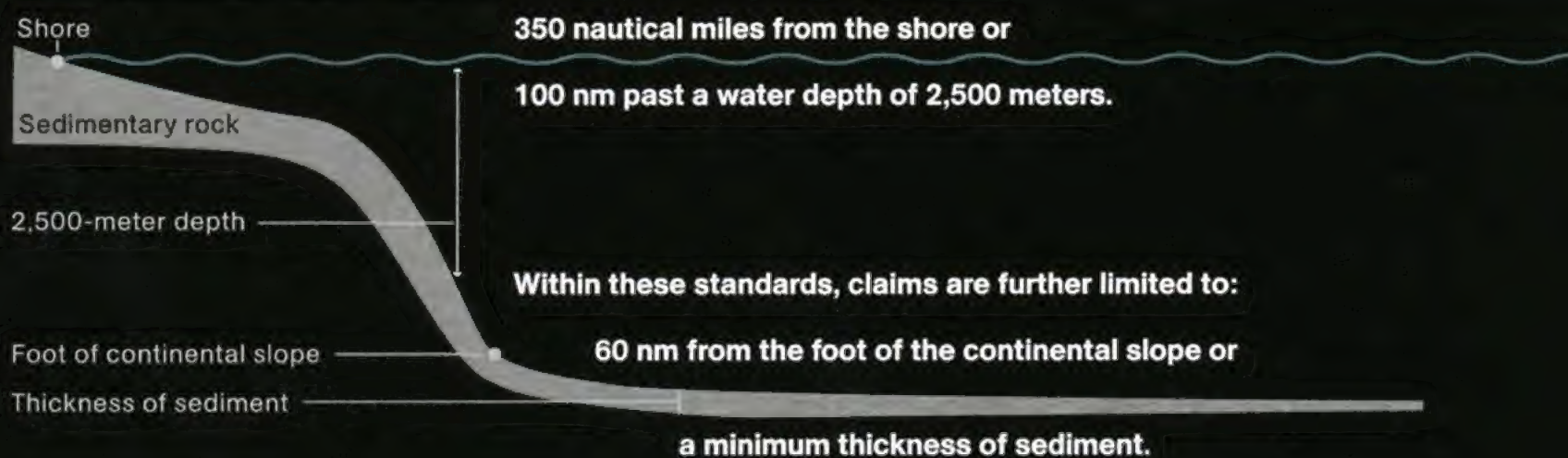
SEARCHING FOR THE EDGES OF CONTINENTS

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THE SEAFLOOR'S CONTOURS Until recently, charts of submarine features in the icebound north were sketchy. Now a different world is emerging, as mapping expeditions with high-tech tools reveal areas that are much higher or lower than previously believed (below). Such details are crucial: A country must describe the shape of the seabed and the thickness of sediment to support its claims.



Continental shelf claims cannot extend beyond:



1 NAUTICAL MILE = 1.15 STATUTE MILES

MAP AND GRAPHIC BY BILL RANKIN
SOURCES: IBCAO AND NATIONAL GEOPHYSICAL DATA CENTER (NGDC),
NOAA (SEAFLOOR ELEVATION); IBRU, DURHAM UNIVERSITY (BOUNDARIES);
UNITED NATIONS CONVENTION ON THE LAW OF THE SEA (GRAPHIC)



A new liquefied natural gas plant sends up a test flare near Hammerfest, Norway. The raw fuel arrives by pipeline from the Snøhvit field 90 miles away in the Barents Sea. Pouring in for jobs, workers from 46 nations have transformed the once faded fishing village.

charges under it, and scientists traveling by helicopter to lay out tracks of seismic sensors. In a 2008 follow-up, Canada shipped in 33,000 pounds of explosives and 1,100 pounds of fuel from Montreal on an icebreaker, and then 30 people worked for 30 days in minus 30°F temperatures. In Russia, in a dingy office down a backstreet in St. Petersburg—quarters far less grand than Chilingarov's in the Duma—a geologist leading the country's little-noticed mapping effort showed me a photo of the seismic work on its side of the Lomonosov: men pushing a scary, golf-cart-size mesh sack of dynamite into an ice opening. He was nearly

attacked by a mother polar bear and two cubs in the line of mapping duty.

Mayer has his own hurdles: Sonar works poorly in ice, and in a normal year the *Healy* must limp along at three or four knots to get any data at all. Unfortunately for the Arctic, but fortunately for the mission, this year is far from normal. The enduring mystery of our first week is the location of the ice cap. Our resident ice scientist, Pablo Clemente-Colón, a cigar-smoking Puerto Rican, keeps promising we are about to run into it, wielding satellite reports—official products with names such as AMSR-E, QuikSCAT, and RADARSAT—that show it just



hours away. Instead we hit only stray patches of first-year ice—or nothing at all. The ice edge seems to retreat faster than we approach, moving too quickly for the satellites to keep up. We are chasing a ghost.

ALREADY IN THE 1970s AND 1980s, Siberia and Alaska had parallel petroleum booms, but these were mostly on land. Increasingly drillers are looking offshore—and increasingly a former fishing town in Norway, Hammerfest, is a symbol of what may come. When I visit Hammerfest, home to the world's

newest and northernmost liquefied natural gas facility, Snøhvit, I expect to see the start of production—but it is a false start, one of many. The gas field is in the Barents Sea, 800 feet underwater, connected by 90 miles of pipes to an ultramodern plant. The plant, on a grassy island abutting the beautiful 9,400-person town, is northern Norway's largest ever industrial project. Viewed from the Hammerfest shopping mall, it is a tangle of smokestacks, lights, and tubes, backed by a fjord and a row of snowy peaks.

For now, StatoilHydro, the operator, will move gas up the pipes, process it, and export it by tanker—half of it to Cove Point, Maryland, half to Bilbao, Spain. But soon carbon dioxide, separated from the natural gas, will travel the other direction down the pipes: StatoilHydro will inject it into the seabed to combat global warming. Snøhvit promises to be one of the world's cleanest petroleum projects. During one test run, however, the winds blew ash from Snøhvit's flares—chimneys burning off excess gas—that turned cars and homes black. StatoilHydro brought in doctors to test for carcinogens and handed out reparations checks to angry residents.

It is a measure of petroleum wealth's appeal that I find only one local politician opposed to the plant: a 19-year-old from the revolutionary-socialist Red party. Snøhvit pays Hammerfest \$22 million a year in property taxes. The town is awash in new projects: renovated schools, a bigger airport, a sports arena, a "full-digital," glass-walled cultural center. Strollers are everywhere in the snow-covered streets. It is easy to forget that Hammerfest was recently a dying town, shrinking in population, the most violent place in Norway. In his bay-front office, a local official named Snorre Sundquist is circumspect about Snøhvit. "People didn't like the soot," he says, "but they accepted it."

It is 2 p.m., the Arctic in winter, and it is becoming dark. I step out just in time to see Snøhvit fire up after months of soot-related repairs. A flame spouts hundreds of feet from the tallest chimney, dwarfing the mountains, bathing the town in orange light. From two miles away,

The ice edge seems
to retreat faster than
we approach, moving
too quickly for the
satellites to keep up.
We are chasing a ghost.

I can hear it burn, I can feel the heat on my face.

Whether the future of the Arctic will look like Hammerfest—petroleum plants dotting the coast, an economy running on fossil fuels, and an ice sheet destroyed by them—depends on the world's capacity for irony, and perhaps more on how much oil there really is. In July 2008 the USGS published its "Circum-Arctic Resource Appraisal." It estimated that 13 percent of the world's undiscovered oil, or 90 billion barrels, and 30 percent of its undiscovered natural gas, or 1,670 trillion cubic feet, may be hiding here. But given the unexplored nature of the Arctic, the USGS report is by definition a desktop study: reliant on analogues and best-guess geologic assessments. It uses little of the recent, proprietary seismic work collected by oil companies, settling for older, publicly available data.

Other reports are less rosy, suggesting that the Arctic holds plentiful gas, but far less oil. And in any case, most of the petroleum appears to be near shore—not subject to continental shelf claims because it is within the 200 nautical miles nations already control. The race for the Arctic may be about oil, but it is about the oil that governments hope is there, not the oil they know is there.

The experts best equipped to assess the Arctic's prospects are the oil companies, and a few weeks after my Snøhvit visit, I witness their tacit vote of confidence: a bidding war for nearshore exploration blocks in the Chukchi Sea. The 488 blocks are auctioned off in the Anchorage, Alaska, public library over the protest of environmentalists who want a decision on the polar bear's endangered species status before a sell-off of its habitat. They go for a record \$2.66 billion—43 times what the government expected.

There is a second misconception about the race for the Arctic: that it is necessarily a race between nations; if America is to win, Russia must

lose. But the market for petroleum is globalized, and so is the hunt, and so are the corporations. The companies vying for projects in Alaska—Shell, StatoilHydro, Chevron, Gazprom, BP, ConocoPhillips—are the same companies vying for projects in Russia and Canada and Norway and Greenland, and their oil is sold on an international market. Where we draw the lines does matter—this will determine who sets the environmental rules and who gets the royalties—but it matters far less than the fact that the lines are being drawn at all. Unless the Arctic countries agree, unless there is legal certainty, companies will not purchase mineral leases, because it won't be clear who can sell them. And the Arctic will remain a wilderness.

IT IS SATURDAY, FOGGY AND COLD, TWO weeks into the *Healy* cruise, when we learn we have broken a record. "It's confirmed," ice scientist Clemente-Colón says, looking up from his computer. "It happened a few days ago." The ice cap has shrunk to its smallest extent in modern history. The ship is now at 77 degrees north, having looped south from a high point above 81 degrees, cutting in and out of the ice sheet, and is scanning the Chukchi Plateau. Clemente-Colón has found occasional pieces of multiyear ice big enough to support a tracking buoy—when out deploying his first one, he cheekily pulled out a tiny Puerto Rican flag—but here most of the ice is patchy, not a solid mass but a series of floes, like asteroid belts. The *Healy* crashes through. The sun appears, and sailors hit expired survival rations off the helideck with a golf club. They plan a barbecue. A curious feeling, that of being witnesses to a historic moment, washes over the science crew.

In the lab, data stream in unobstructed. We speed up to 10 knots, then 13, then 15. Up on the bridge, my roommate is keeping a tally of seals and polar bears. "Man, last year we were seeing 50 seals a week," Olemaun says. "Now we're lucky if we see one each day." He sees one: "Man, that poor seal." Then reconsiders: "Just imagine if I had my harpoon."

We get reports that the Northwest Passage—



On a joint voyage in the frozen Beaufort Sea, the Canadian icebreaker *Louis S. St-Laurent* crunches on ahead so the *Healy* can run its sonar on a quieter course. Such cooperation brings countries closer to their common goal of developing the region's great potential.

the long-sought shipping route across the top of North America, the elusive goal of explorers John Ross, William Edward Parry, John Franklin—is ice free for the second year in a row. We learn that the USGS has released a polar bear study: If the melt continues, the world's population—estimated at 22,000 bears—will shrink by two-thirds by 2050. I get an email from someone on one of Shell's seismic ships. His fleet is looking for oil somewhere to our south—he can't say where, but we just passed within 50 miles of each other.

By the time the *Healy* begins its return, on September 10, the ice cap is the shape of a kidney, just 800 miles across the middle. Olemaun compiles his tally: 17 polar bears, 10 bearded seals, 9 ringed seals, 12 seals of unidentified species, 2 walruses. We learn that walruses are appearing by the dozens on Barrow's beaches: The ice edge, their normal home, is too far away. Locals are distressed, and they are hunting them anyway.

It is a bad summer for ice. It is a bad summer for walruses and polar bears. But it is a good summer for mapping. Before we hit Barrow, the

multibeam reveals scours on the seabed 1,300 to 1,600 feet down—likely scrape marks from an ancient ice sheet. Mayer flies around in his map program, giddy, spinning the image of the scours, hovering above them, skimming the seabed at top virtual speed, awestruck by the world he has revealed. The *Healy* will soon have mapped 6,200 linear miles of seabed in a month—three times what Mayer expected. A NOAA press release will announce the results: Our data suggest that the continental shelf extends more than a hundred miles farther north than previously believed. America is bigger than we thought. Whether it is richer remains to be seen.

The last bear we see is a surprise. It is 2 a.m. at nearly 81 degrees north, and we are in fully open ocean, dozens of miles from the ice pack. Clemente-Colón has decided to place his final buoy into the water—he wants to test if it can transmit when the ice is gone—and most of the crew is awake to watch. Out of the fog, a ten-foot-wide chunk of ice appears—a flash of white, visible for maybe 15 seconds. On it: a polar bear, drifting wherever the ocean wants to take it. □



ANCIENT MARINER

THE BIGGEST, DEEPEST DIVING, WIDEST RANGING

OF ALL TURTLES, THE LEATHERBACK HAS

ENDURED FOR 100 MILLION YEARS.

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A bathtub-size female lazes through warm shallows near Indonesia's Kai Islands; remoras hitch a ride.



Nesting leatherbacks crowd the sands by moonlight at Grande Riviere, Trinidad. The wave-washed beaches they favor can quickly erode or expand, so turtles hedge their bets by scattering nests at random, even at the water's edge.

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BY TIM APPENZELLER

PHOTOGRAPHS BY BRIAN SKERRY



ne late summer day in 1961
a biologist named Sherman
Bleakney got a telephone call
about a strange sea creature

that fishermen had just unloaded on a wharf
in Halifax, Nova Scotia. Bleakney, who lived
nearby, was captivated by what he found there.

Sprawled on its back amid a curious crowd

was an immense black sea turtle tipping the
scales at 900 pounds, with a soft, rubbery cara-
pace, winglike front flippers, and a massive,
conical head like an artillery shell. Bleakney
recognized it as a leatherback, the biggest of all
sea turtles. Leatherbacks, he recalled, were sup-
posed to be creatures of the tropics, as out of
place in chilly, gray Canadian waters as parrots
in a Halifax park.

When Bleakney began asking around,
though, he learned that fishermen saw leath-
erbacks swimming in the waters off Maritime
Canada regularly enough to call late summer
“turtle season.” The conclusion was inescapable,
he wrote in 1965. “Evidently there is an annual
invasion of our cool Atlantic coastal waters by
turtles of tropical origin.” Their southern roots
were obvious from the few dead turtles he exam-
ined. One had a twig from a tropical mangrove
tree stuck in its eye; others carried warm-water
barnacles. Yet the leatherbacks were surviving,
even flourishing, at temperatures that would
kill other sea turtles. Stranger still was what he
found inside them: Their huge stomachs con-
tained masses of chewed-up jellyfish, stinging
tentacles and all, and their gullets were lined
with three-inch spines, angled inward to hold
in all that slippery prey.

*Tim Appenzeller is an executive editor for the mag-
azine. Brian Skerry used special techniques to avoid
disturbing light-sensitive leatherbacks in the dark.*

Bleakney eventually moved on to other stud-
ies—sea slugs were a special passion of his—but
he never stopped marveling at the great beasts
he had encountered on the fishing piers of Nova
Scotia. “It was mind-boggling,” he recalled in a
recent interview with Canadian conservation-
ists. “A reptile of that size, that lives in ice wa-
ter, that can thrive on jellyfish.” Almost 50 years
later, scientists are still astonished at the leath-
erback’s physical prowess, though today wonder
is alloyed with a more modern sentiment: fear
that even before we fully understand the leath-
erback and its epic life story, our own activities
may be driving it to extinction.

Over the past 25 years, researchers counting
the leatherbacks that crawl out to nest on tropi-
cal and subtropical beaches have sounded the
alarm as the numbers plummeted: from tens or
even hundreds of thousands of turtles on the
Pacific beaches of Mexico and Central America
to a few hundred today; from thousands in Ma-
laysia to a handful. The International Union for
the Conservation of Nature lists leatherbacks as
critically endangered, and to list the many ways
they die is to despair: tangled and drowned in
fishing gear, choked on drifting plastic bags,
struck by ships, slaughtered for meat, doomed
even before they can hatch when nests are dug
up and the eggs sold as food or aphrodisiacs.
The leatherback lineage goes back a hundred
million years—“it was on the beaches when *T. rex*
was the primary predator,” says Scott Eckert
of the Wider Caribbean Sea Turtle Conserva-
tion Network at Duke University. Now, in some
parts of its range, it is at the end of the line.

Spend time with researchers like Eckert,
though, and you’ll begin to see this turtle as a
survivor. The leatherback can dive nearly a mile,
swim across oceans, and keep itself warm in wa-
ter close to freezing. It survives on a diet that
few other creatures can stomach. And, most im-
portant, it keeps its options open. Other sea tur-
tles are faithful to specific nesting beaches and
feeding grounds, which makes them especially
vulnerable as human pressures increase. But
the leatherback can be more of an opportunist,
exploiting favorable conditions—undeveloped



Hatchlings struggle to the surface (below) after breaking out of their eggs with a special tooth—first steps on a perilous journey to adulthood. Vultures feast (left) when the beach churns with baby turtles, and predatory fish wait offshore. To compensate, a female lays hundreds of eggs in multiple clutches each nesting season.

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A hatchling gets its first taste of salt water on Trinidad's Matura Beach. Females emerge after decades at sea as 600-pound adults ready to nest for the first time, often at or near where they hatched. Males never come back to land.

nesting beaches, rich blooms of jellyfish—as it finds them. “These turtles treat the entire ocean as their pond,” says Jeanette Wyneken, a biologist at Florida Atlantic University. The result is that, in some regions, leatherback populations are actually on the rise.

SPRINGTIME ON MATURA BEACH, six miles of palm-fringed, surf-washed sand on the east coast of Trinidad. By day the beach looks as if giant dune buggies have romped across it. Chevron-pattern tracks five feet wide twist over the sand, interrupted by shallow, car-size pits. By night the real earthmovers appear. They advance not with a roar of engines but with a whisper of sand, the thump of bodies heaving forward inch by inch, the sigh and grunt of heavy effort. The leatherbacks are nesting.

Black and gleaming in the moonlight, each female drags herself from the surf, front flippers scoring the sand as she pulls herself along, and settles in to dig. Scooping with her rear flippers, she excavates a shaft; when she can no longer reach the bottom, she begins to lay her eggs, a glistening cue ball every few seconds. Once she has a cache of 80 or so, she fills in the nest, sweeping her front flippers to smooth out the spot. Then she drags herself a few feet away and makes more giant sand angels—a decoy nest that may serve to confuse predators. After two or three hours on the beach, her throat rosy with exertion, she returns to the sea.

Leatherbacks have been nesting on Matura Beach for as long as anyone can remember, even during the bad years of the 1970s and '80s, when the beach reeked from butchered turtle carcasses rotting in the sun and the sand was pocked with holes dug by egg poachers. These days the turtles nest unmolested, their domain patrolled by Nature Seekers, a local conservation group. The number has shot up, from a few hundred nesting each year a decade ago to perhaps 3,000.

Turtles are practically storming the beaches of Trinidad. Last year at Grande Riviere, a beach just a half mile long, 500 leatherbacks a night vied for nesting space, a scrum so dense they dug up each other's nests, leaving a windfall for vultures and stray dogs. Elsewhere on the island, turtles have begun colonizing beaches that were empty just a few years ago. All told, Eckert estimates that 8,000 leatherbacks visited Trinidad to nest last year.

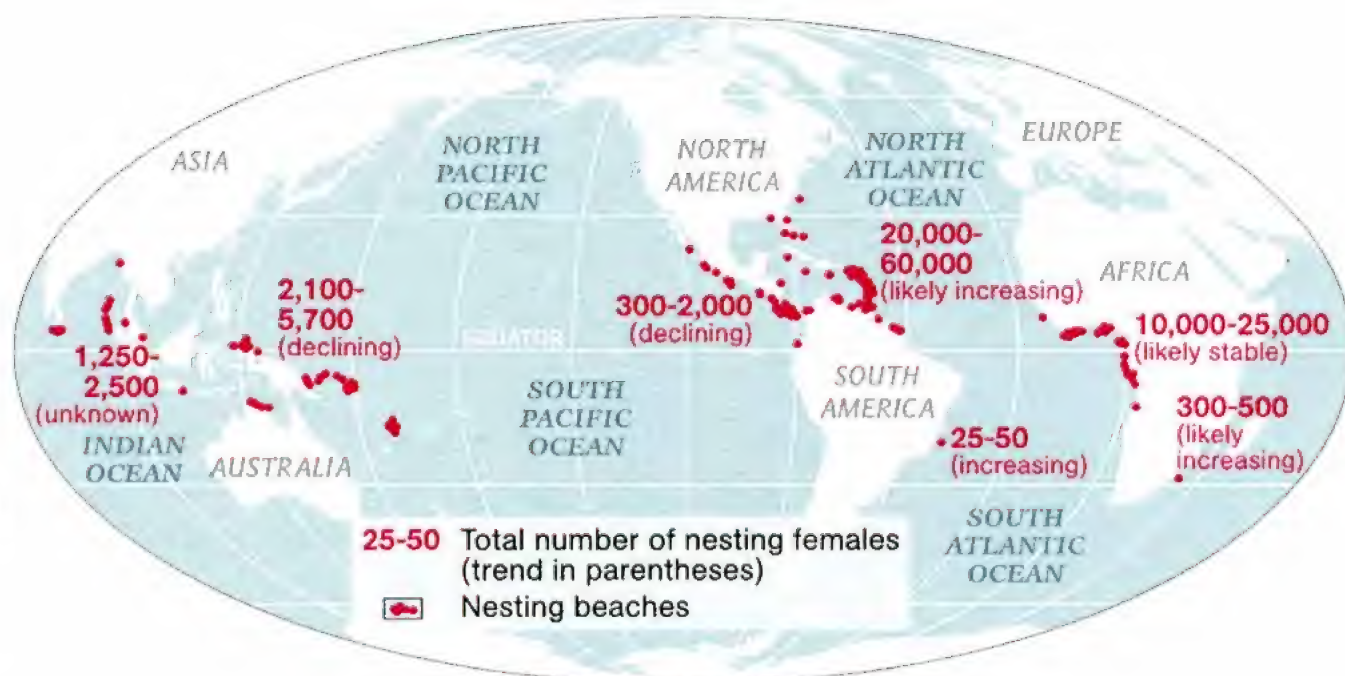
The numbers are all the more remarkable because of the gantlet the turtles run just offshore. Leatherback nesting season is also the time when the hundreds of fishermen in northeast Trinidad set curtains of net a few miles offshore, hoping for a load of mackerel or kingfish. Increasingly, they catch half-ton turtles instead.

The fishermen are no happier about it than Eckert and his colleagues.

At the fishing pier in the small port of Toco, Shazam Mohammed is skinny, shirtless, and

How many?

The only leatherbacks researchers can count reliably are females on nesting beaches. Totals, including juveniles and males, are several times larger. Yet the trends are clear: Atlantic numbers are rising, but human impacts and natural ocean fluctuations have driven Pacific numbers down alarmingly.



LISA R. RITTER, NG STAFF

SOURCES: BRYAN WALLACE, CONSERVATION INTERNATIONAL; SCOTT ECKERT, WIDECAST, DUKE UNIVERSITY; SCOTT BENSON AND PETER DUTTON, SOUTHWEST FISHERIES SCIENCE CENTER, NOAA; MIKE JAMES, CANADIAN SEA TURTLE NETWORK; STATE OF THE WORLD'S SEA TURTLES (SWOT); OBIS-SEAMAP



Raising hatchlings in captivity helped University of British Columbia zoologist T. Todd Jones learn how young leatherbacks develop. On a diet of squid gelatin, one reached a hundred pounds. Harnesses, as on this two-year-old, kept the animals from crashing into tank walls. "There's no tank as big as the Pacific Ocean," Jones said.

furious. He gestures at a heap of green fishnet, tangled and cut. "All those nets are chopped up," he says—slashed to remove leatherbacks that blundered into them the night before. "If we make 200 Trinidad dollars [about 30 U.S. dollars], we have to pay 500 to fix the nets." The turtles, it's safe to assume, did not fare well either. "Damn leatherbacks. I'm not wasting time saving them—if I catch a turtle, I will destroy it."

Eckert and colleagues from the NOAA Fisheries Service, hoping to find a way for nesting leatherbacks and coastal fishermen to coexist, have worked with local people to test modified nets that catch fewer turtles. Meanwhile more and more of the fishermen are looking for other ways to make a living during turtle season. Even so, Eckert and others estimate that a thousand or more leatherbacks die every year off

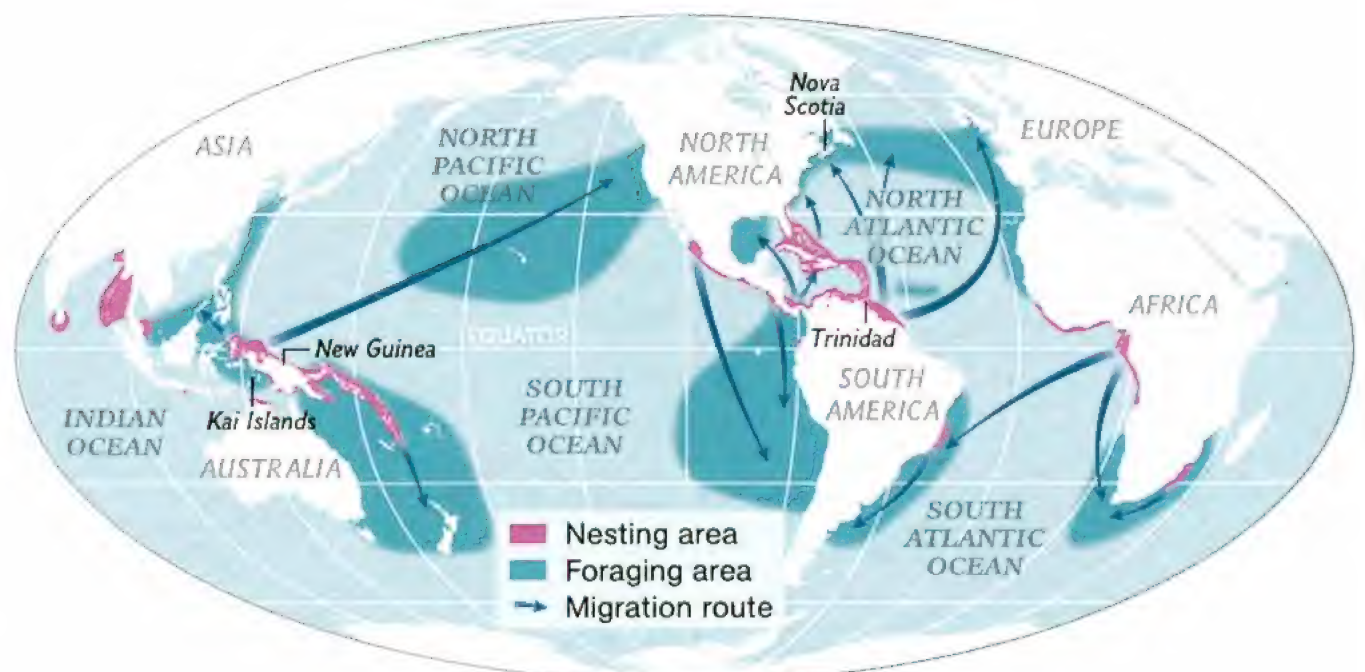
Trinidad, drowned in nets or hacked out of them by desperate fishermen.

And yet the tide of nesting leatherbacks keeps rising, not just in Trinidad but around the Caribbean—in St. Croix, along the northern coast of South America, even in Florida.

Stopping the slaughter on nesting beaches, as Nature Seekers and other organizations have done, must have helped, says Eckert. "But I'd be hesitant to say there's a direct link between conservation and the kind of increase we're seeing." It's too early, he thinks, for the biggest benefit of beach patrols—saving countless eggs from being harvested and sold—to be paying off. No one is sure how long it takes leatherbacks to mature. But recent research, based on growth layers in tiny bones that encircle the pupil of the leatherback eye, suggests it could take 30 years, which


Where do they go?

Leatherbacks must lay their eggs in warm sands, but they often migrate to cold, far-off waters to feed on jellyfish. In the longest known journey, turtles that nest on New Guinea swim a 6,500-mile stretch to coastal California and Oregon, and then back, perhaps as often as every three years.





She had just laid her eggs on a dark Trinidad beach when conservation workers hoisted this female for a weigh-in, captured by an infrared camera. As her robust 1,087 pounds show, Atlantic leatherbacks are thriving, thanks to rich foraging grounds off Canada.

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would mean that the hatchlings saved over the past few years can't be contributing yet to the surge of turtles hitting the beaches.

Thousands of miles from the warm sands of Trinidad, something else seems to be going very right for the leatherbacks of the Atlantic.

LEATHERBACKS ARE BUILT to travel. On the beach they look as out of place as a submarine in dry dock, but in the water "they are the most graceful creatures you've ever seen," says Scott Eckert. "This is one of the finest hydrodynamically designed animals on the planet. They can probably swim as easily as rest."

Unlike the massive, overhanging shell of other sea turtles, the leatherback's flexible, form-fitting carapace merges almost seamlessly with its thick neck and muscular shoulders. Seven ridges run the length of the shell—adaptations, perhaps, for smoothing and directing the flow of water. The turtle's head is a prow; the carapace tapers toward the back like a teardrop.

The leatherback also propels itself with an efficiency no other sea turtle can match. All sea turtles can fly through the water by flapping their flippers vertically, generating thrust on both the upstroke and the down. But while other species sometimes shift to a less efficient paddling motion, the leatherback uses its longer flippers exclusively as wings. "It's almost pure underwater flight," says Jeanette Wyneken, who has analyzed leatherback swimming with high-speed video.

Today, evidence of leatherback migrations comes not from the twigs and barnacles that told their story almost a half century ago but from satellite transmitters attached to the turtles on the nesting beaches or at sea. Satellites have tracked them traveling the length and breadth of the North Atlantic, from the Caribbean up to Canada and across to the Canaries and the Irish Sea. In the Pacific, satellite-tagged turtles have made the longest crossing of all: 6,500 miles between nesting beaches on New Guinea and the coastal waters of Oregon and California.

Their travels often take leatherbacks into water well below 60°F, more hospitable to whales

and seals than to sea turtles. But these turtles can shrug off the cold. Rest your hand on a leatherback's meaty shoulder and you will feel a faint but definitely nonreptilian warmth—the product of so-called gigantothermy, a set of features that may keep leatherbacks 12 degrees F or so warmer than the water they swim in. As the term suggests, part of it is sheer mass: Big animals naturally retain heat. By packing thousand-pound turtles in a thousand pounds of ice (yes, this was an actual experiment, and the animals recovered quickly), researchers found that blood flow to and from the flipper surface shuts down intermittently, keeping body heat in the body core. A thick jacket of fat helps too. Leatherbacks end up with the best of both worlds: a thrifty, slow reptilian metabolism but the ability to function—swim, feed, digest—in cold water, which is where some of the densest concentrations of jellyfish can be found.

DECADES AFTER Sherman Bleakney abandoned leatherbacks for sea slugs, a young scientist named Mike James took up where he had left off. In out-of-the-way fishing villages all around Nova Scotia, James introduced himself and tacked up posters asking, "Have you seen this turtle?" in big letters, with a picture of a leatherback and a toll-free number. The very first year, in 1998, fishermen around the province called in 200 sightings.

The next summer, James drove into the small port of Neil's Harbour, on Cape Breton Island at the northern end of Nova Scotia, and knocked on a door belonging to Bert Fricker. Bert was



Prey

Among the largest jellyfish, at some ten pounds, the lion's mane is a favorite leatherback meal.

SWIMMING MACHINE

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More than a hundred million years of evolution have outfitted the leatherback turtle with adaptations for supremely efficient swimming, deep diving, and surviving in frigid water—all on a diet of low-calorie jellyfish.

Flexibility

Coin-size plates of bone interlock in a pliable shell that may compress at extreme depths.

Streamlining

A teardrop body shape and keel-like ridges ease flow across the shell.

Sensing the Seasons

A patch of pale skin lets light reach the pineal gland, which may sense changes in day length and cue migration.

Brain

Blubber

Stomach

Lung

Ventricle

Atrium

Pulmonary artery

Keeping Warm

Cool blood returning from the flippers is warmed by outgoing blood before reaching the body core. In very cold water, blood flow to and from the flipper surface may shut down intermittently.

Size

Immense mass—up to 2,000 pounds—helps the turtle stay warm in cold water by slowing heat loss.



Diving

A sphincter closes off blood flow to the lungs, conserving energy.

Feeding

Spiny barbs line the esophagus, trapping slippery prey.

Salt Removal

Massive salt glands capture excess salt from the turtle's jellyfish diet and excrete it in viscous tears.

MARIEL FURLONG, NG STAFF; ART BY RAÚL MARTÍN
SOURCES: JEANETTE WYNEKEN, FLORIDA ATLANTIC UNIVERSITY;
BRYAN WALLACE, CONSERVATION INTERNATIONAL

from a fishing family, but the cod stocks had collapsed in the early 1990s. He generally spent the late summer chasing swordfish, but they were disappearing too; a 614-pounder he had harpooned a month earlier turned out to be the last one anyone from Neil's Harbour ever landed. So Bert Fricker and his brother Blair had time to spare for the eager young man with a giant, custom-made hoop net tied to the roof of his car and a request: Take me out on your boat to catch a leatherback, alive. "We kind of thought it was a joke," says Bert, "but it sounded like fun."

Since then, working every summer and early fall with Bert and Blair aboard their two boats, James and his colleagues from the Canadian Sea Turtle Network in Halifax have captured and released several hundred leatherbacks. When they haul in an animal, one of the first things they do is check for a tag—a metal strip crimped onto a rear flipper or a microchip injected into the shoulder by researchers at a distant nesting beach. Over the years, they have logged a veritable UN of origins—northern South America, Central America, Caribbean islands including Trinidad, and Florida. "We are a pooling area for turtles from the western Atlantic," says James.

The leatherbacks make the long journey and endure the chilly water for one reason: to feast. Even from the boat, it's clear that the turtles here are absorbed in eating. When Bert or Blair spots one—scanning the gray chop, they are usually the first to see the swell of a carapace or the black knob of the head—it often has pink skeins of jellyfish tentacles trailing from its mouth and its head tipped back to swallow. Maneuvering the boat close, they lean out holding a small instrument package with a suction-cup base and press it onto the animal's back. For the next several hours, the gadget tracks the leatherback as it browses the rich jellyfish gardens tens of feet below the waves.

Jellyfish is meager sustenance—by one estimate, it has less than 2 percent of the calories a true fish has. Even with their thrifty metabolism and efficient swimming, leatherbacks must be eating vast amounts. Last year, with a video camera built into the suction-cup instrument

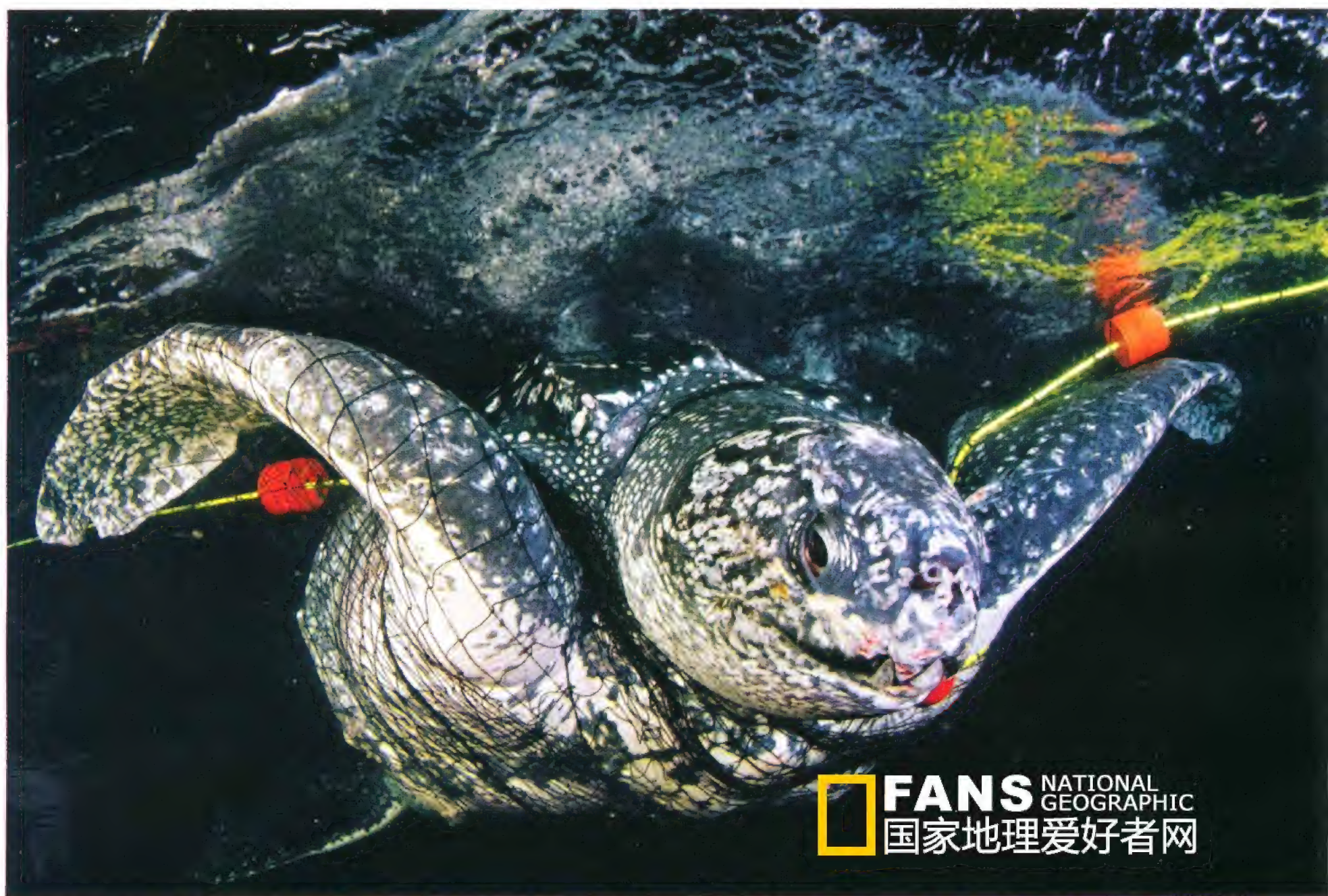
package, James glimpsed the scale of the gluttony. In the footage, recorded at a depth of 60 feet or so, the turtles devour jellyfish after jellyfish, quickly reducing each billowing creature to a cloud of debris. In three hours, one leatherback ate 69 jellyfish—a species called the lion's mane, as big as a trash-can lid and weighing ten pounds or more. It's easy to believe that a half-ton turtle eats its weight in jellyfish a day.

THE JELLYFISH were surely around back in Sherman Bleakney's day. But scientists wondering how the leatherbacks of the Atlantic could be thriving against heavy odds say the ocean may be even richer now. Maybe climate change has changed the dynamics of the North Atlantic, sweeping in extra nutrients that favor jellyfish blooms. Or maybe overfishing triggered the ecosystem shift: Old-timers say leatherbacks started arriving in force around the time the fisheries off Neil's Harbour collapsed almost 20 years ago. As cod, haddock, and swordfish dwindled, snow crab and lobster burgeoned, giving the town a new lifeline. No one has tracked the population of jellyfish, but James thinks they must have multiplied along with the shellfish. "All of a sudden what's on the scene is a jellyfish-dominated ecosystem. Turtles aren't stupid. That's why there are so many more than before." Both scenarios carry the same irony. Human activity—so damaging to the ocean and most of its creatures—may actually be giving the Atlantic leatherbacks a boost.

Before anyone celebrates nature's resilience, though, it's worth remembering what has happened in the eastern Pacific. There every trend seems to be running against the turtles: poachers and developers on the beaches, drift nets and longlines at sea, even the ocean itself. Nesting on the west coast of Mexico and Central America, the eastern Pacific leatherbacks migrate south, across the Equator, to feed in the nutrient-rich waters that well up from the depths off Chile and Peru. But every few years, in an El Niño event, currents shift, the upwelling shuts down, and the equatorial Pacific becomes a virtual desert. Each lean year off South



Each year thousands of leatherbacks die when they blunder into curtainlike gill nets set by Caribbean fishermen. Off Trinidad, researchers (left) tested shallower nets, which snared fewer turtles without reducing the fish catch. In the water during the study, photographer Brian Skerry freed the entangled turtle below before it could drown.



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Trailing tentacles from his latest meal—a lion’s mane jellyfish—a male bulks up in nutrient-rich waters off Nova Scotia. During four months or so on Canadian feeding grounds, leatherbacks eat hundreds of pounds of jellyfish a day to store energy.

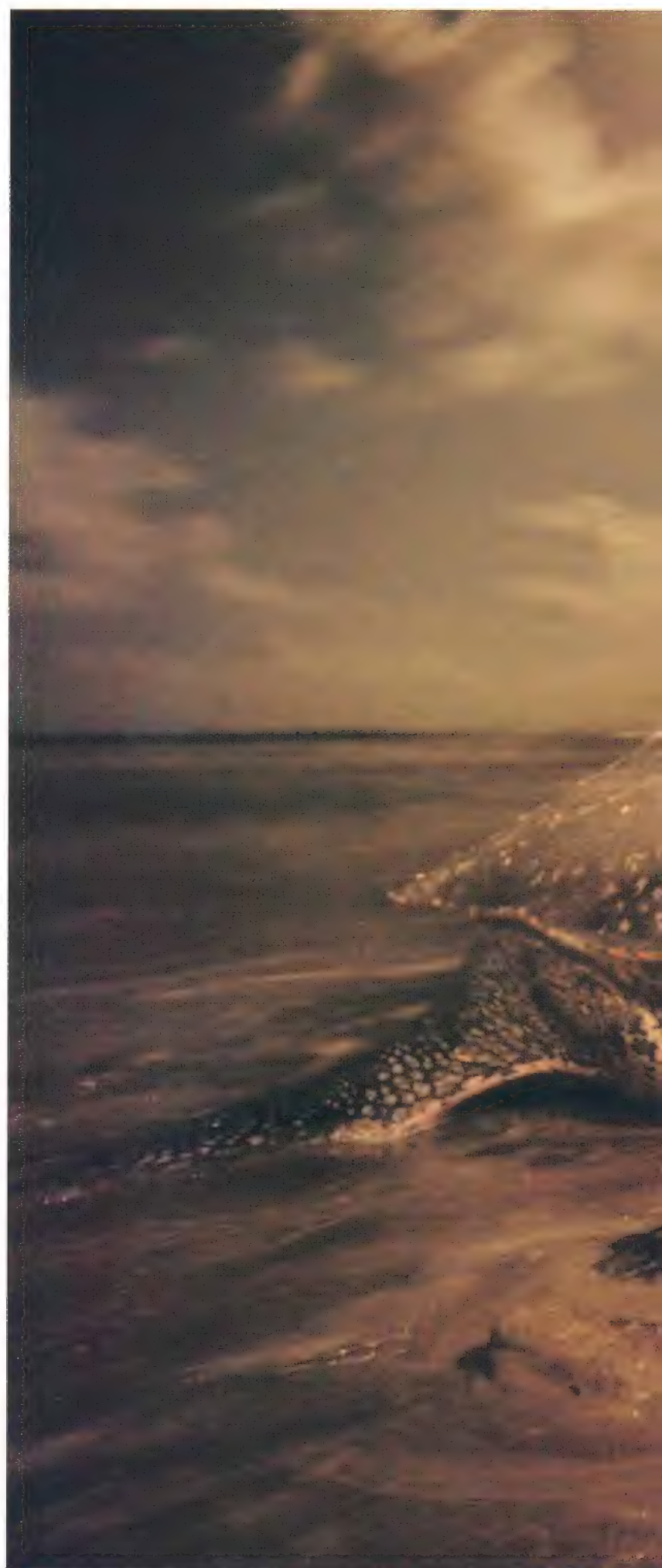
America brings a sparse nesting season the following winter, researchers have found, with only a handful of females visiting beaches that might normally see a hundred or more. Even in good years leatherbacks in the eastern Pacific show the effects of scarcity: They are several inches shorter on average than in other oceans, nest less often, and lay smaller clutches.

El Niños have been stronger lately, perhaps because of greenhouse warming, although a decades-long natural cycle in the Pacific also plays a role. Either way, the food shortage seems to have made the leatherback population in the eastern Pacific all the more vulnerable to pressure from poachers and fishermen, and the turtles there are now a short step away from extinction.

Yet 25 years ago, the eastern Pacific population may have been the largest on the planet. In Mexico alone, beaches that are now almost barren may have hosted as many as 75,000 nesting females every year. The precipitous fall is a reminder of how fast human impacts on the ocean can unfold, and how unpredictably they can combine with natural factors. In the Atlantic, ecosystems could change again, this time to the turtles' detriment; a new fishery could begin taking a toll; or some other, unforeseen factor could wipe out the gains of recent years.

ON CROWDED nesting beaches you will sometimes see leatherback females collide—one of them determined to nest; the other, her business done, heading back to the water. Neither gives way. Each pushes forward in the grip of her primordial needs, until sheer muscle overcomes friction and they grind past each other.

Watching the contest, you sense the life force that has carried leatherbacks past every obstacle for a hundred million years. That span of time saw a giant asteroid fall from the sky, ice sheets grow and collapse, and countless other creatures flourish and die out. But leatherbacks went on roaming the ocean and climbing the beaches to nest. In the long run—the only scale that matters for a creature this ancient—humans may turn out to be just one more obstacle. □



A faint amber flash froze a ghostly image against the moonlit backdrop of Matura Beach as the female heaved herself from the surf. This ancient leatherback nesting ritual is now widely endangered.



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Hovering over a river in China's Yunnan Province, Fritz Hoffmann photographs a couple on their way to market.

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ON ASSIGNMENT Cable Guy "I wasn't concerned for my safety," says photographer Fritz Hoffmann, referring to his time spent dangling from a zip line to shoot this month's "Searching for Shangri-La." "I was more concerned about dropping a piece of equipment," he says. However, his precarious position did have a plus: Emotions on his subjects' faces, like the two shown here, were lit perfectly for him by the open sky.



Shell Game He may be a vice president at Conservation International, but Roderic Mast has a secret identity. Whenever he puts on his custom-made turtle suit (left, at Rosalie Beach on the island of Dominica), you can call him Mr. Leatherback. Mast has worn the costume all over the world to bring attention to the endangered reptiles. This month his turtle touting includes the Great Turtle Race on ngm.com/leatherbacks. Watch online as leatherbacks tagged with tracking devices make their way from Nova Scotia's waters to Caribbean nesting beaches.



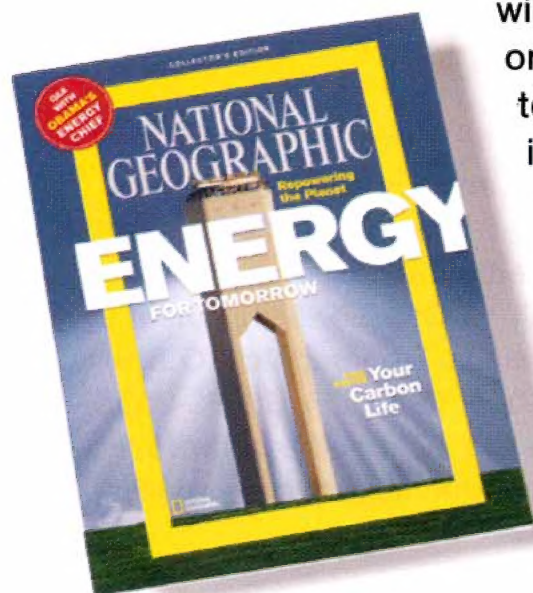
Mammoth Find After a Siberian reindeer herder and his sons stumbled on a frozen mammoth calf some 40,000 years old, it was stolen, sold to a shop owner, then recovered by scientists, who set out to learn how the ancient baby lived and died. A model (above) helps tell the story in *Waking the Baby Mammoth*, airing on National Geographic Channel; check local listings. What long-frozen secrets will be revealed?



COLLECTOR'S EDITION Fueling a Revolution

Energy for Tomorrow may be a potent weapon in the battle to convert climate change skeptics. Compelling articles by author and environmentalist Bill McKibben tell what will happen if nothing is done: Polar ice will continue melting, seas

will rise, cities will drown, and life on Earth will be nothing like it is today. The hopeful news is that it's not too late to change Earth's fate, if we employ large-scale efforts like solar and wind power and take small steps like installing energy-efficient lightbulbs. The special issue is available on newsstands March 31 (\$10.99).



PEOPLE BEHIND THE STORIES

■ **Tom Mueller** The subject of this issue's "Ice Baby" is Lyuba, a frozen, month-old mammoth found in Siberia.



One theory holds that she got stuck in mud, sank out of sight, and stayed entombed

for about 40,000 years. The story's author, seasoned writer Mueller, says he saw how that scenario might have played out. "One evening," he says, "a DNA expert on our expedition washing dinner dishes in the Yuribey River became mired in the quicksand-like bank—and was slowly sinking. It took a chain of four people to get her out. The mud made a loud pop as it reluctantly released her, though it claimed her shoes."

■ **McKenzie Funk** As the Arctic ice cap melts and the race for resources beneath it heats up, journalist Funk

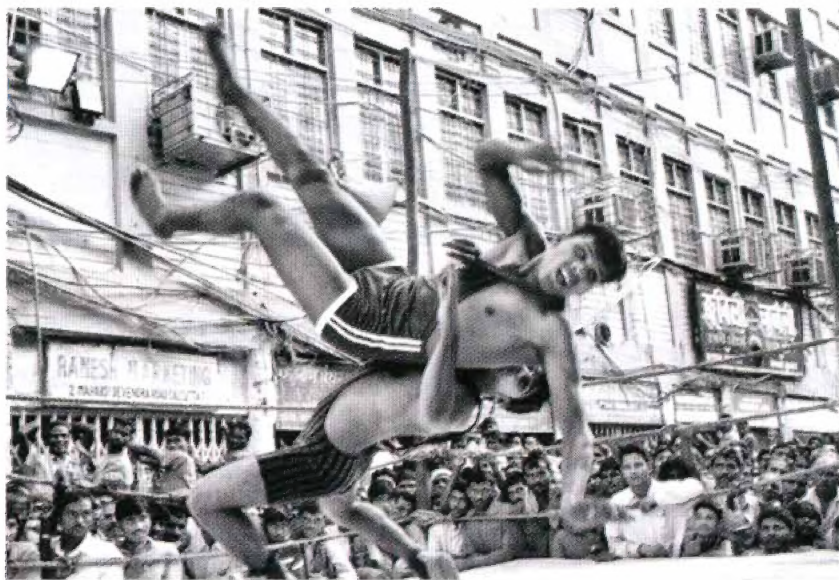


warmed to his work. Writing this issue's "Arctic Landgrab," he spent a mostly

comfortable month on an icebreaker, enjoying movie nights, bingo games, and Internet access. However, he says, certain maritime traditions—such as the hazing of sailors new to the Arctic—remain firmly in place. "In the old days you'd be tossed overboard. These days you get blindfolded, dumped in tanks of mustard and coffee grounds, and hosed down." There was some good news: "At the end I got a certificate. I'll never have to endure that again."

INSIDE GEOGRAPHIC

Prize Photos The judges of the English language portion of the National Geographic International Photography Contest were captivated by the “mysterious style” of a woman’s portrait, a cow’s “sense of dignity,” and an unlikely urban scene in India. The photographers of these three images each received a Leica D-Lux 4 digital camera. The contest’s winning and honorable-mention photographs can be viewed at ngm.com.



PEOPLE **Joshua Monaghan** Enmore, Australia
His subject wasn’t in the mood to pose for an “honest” portrait. “Maybe that helped the photo,” Monaghan says.

PLACES **Subhrajit Basu** West Bengal, India
Wrestlers vie before a rapt crowd in a business district, Basu’s vision of the “unexpected” quality of Indian life.

NATURE **Wendy Erlendson** Manitoba, Canada
“Cows seem to like me,” says Erlendson. To get her angle, she hugged the ground—behind the safety of a fence.

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FLASHBACK



Arctic Fix A local woman mends the fur jackets of Robert Peary's team. He slept fitfully that night—"owing to bugs!" he wrote—during a Greenland expedition in 1894-95. The U.S. Navy commander identified her as "Ahhu, the plump comfortable wife of burly Ahngeenyah," whom he met in a Saunders Island village. With funding from the National Geographic Society, the explorer sought to become the first to set foot on the North Pole. A century ago, in April 1909, he claimed victory: "The pole at last.... My dream and ambition for 23 years!" Peary was doubted, but later vindicated. Historians now believe he came within a few miles of the geographic pole—near enough to deem his mission a success. —Marc Silver

➤ **Flashback Archive** Find all the photos at ngm.com.

PHOTO: ROBERT E. PEARY, NATIONAL GEOGRAPHIC STOCK

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